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Antecedents of Energy Literacy and Energy Saving Behaviour: A Mixed Methods Approach

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A Mixed Methods Approach

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Thesis Abstract

Energy conservation can mitigate significant issues such as climate change and fuel poverty, yet the determinants of this behaviour are poorly understood. It is important to understand the antecedents of energy conservation in order to effectively stimulate this behaviour in society. Traditional models have focused on normative and intentional processes to explain environmental behaviour, but have proven largely unsuccessful for predicting energy use. Considering that day-to-day energy behaviour is likely to be habitual and context dependent, models such as the Comprehensive Action Determination Model (CADM, Klöckner & Blöbaum, 2010), which have integrated these factors with more traditional antecedents of behaviour, may better account for people's actions. The early research in this thesis tests the application of this model to energy saving behaviour using a mixed-methods approach. Findings show that such a model is suitable to account for the drivers of energy behaviour, particularly because of the important role of habits and situational influences on this behaviour.

Although this model can successfully predict daily energy behaviours that involve the routine curtailment of household energy use, one-off energy efficiency investment behaviours are unlikely to be determined by the variables considered by the CADM. That is, these behaviours may be more dependent on people's understanding of the energy consumption in their household, or their energy literacy. Therefore, the second part of this thesis investigates the cognitive processes that inform conscious energy judgements to explore the antecedents of this energy literacy. The studies in this thesis uncover an unprecedented variety of energy judgement heuristics in this decision-making process, and these heuristics are further investigated, again using various methods. This thesis concludes that, to maximally facilitate energy conservation, the habitual and situational antecedents of energy saving behaviour, as captured in such frameworks as the CADM, need to be considered alongside the cognitive processes that shape people's energy literacy when designing effective energy conservation interventions that target both routine and non-routine actions.

Chapter 1: Introduction

1.1 The importance of energy saving behaviour

Household energy consumption accounts for a large proportion of the UK's total energy use, and no significant reductions have been observed in this in the past few decades. Although domestic energy use accounted for 24% of total energy consumption in 1970, by 2014, domestic energy use still made up 27% of national energy use, whereas industry managed to reduce its share in the same time by 23% (DECC, 2015a). Household appliances may have become more efficient, but the energy consumption from consumer electronics (i.e. brown goods) is now almost seven times as much as it was in 1970, and home computing has more than doubled since 2000 (DECC, 2015a).

Even though domestic energy consumption has not decreased in the last decades, energy conservation can address various pertinent societal issues. First, a reduction in energy demand can help alleviate the global energy crisis — the long-term decline in the available supply of petroleum which will inevitably result in a failure to meet the increasing demand for energy (Buchan, 2010). Electricity generation can result in both local environmental degradation (e.g. water contamination, air pollution), as well as global environmental problems that may threaten the future existence of life on the planet (Buchan, 2010). A reduction in energy demand and production would decrease the amount of carbon dioxide being emitted into the atmosphere, thereby reducing the anthropocentric contribution to climate change (IPCC, 2007), and is therefore a key component in reaching the 2015 United Nations Climate Change Conference (or COP21) target of not exceeding global warming by 1.5 degrees Celsius. Indeed, the international climate change institutions such as the Intergovernmental Panel on Climate Change emphasise that decreasing the use of fossil fuel reserves for energy production is particularly critical to reach these goals (IPCC, 2013).

Another societal issue that is associated with energy consumption is fuel poverty, which is the condition of being unable to afford to keep one's home adequately heated, which has been operationalised as spending more than 10% of household income on fuel to keep a home sufficiently warm by DECC (DECC, 2015b). The sharp increase in domestic energy prices since 2003 (DECC, 2015) has resulted in a rise in fuel costs. In 2003, more than 10% of the English population was therefore classified as fuel poor (a figure rising as high as 42% in Northern Ireland, DECC, 2015b). Therefore, it is important that energy conservation is a result of efficient use of energy consumption instead of a blanket energy curtailment approach that could reduce well-being.

Studies have found that people do not currently save energy efficiently in their home (Ehrman, 2000; Lindén, Carlsson-Kanyama, & Eriksson, 2006), suggesting an opportunity to improve this energy conservation behaviour. This is despite householders reporting that saving energy is the most important strategy to reduce their impact on environmental problems (Semenza et al., 2008) and saying that are willing to curtail the use of their household appliances (Gatersleben & Vlek, 1998). It is promising, in this context, that households are not only interested in information about energy use and its impact on the environment, but are also willing to change their behaviour in relation to this (Mansouri, Newborough, & Probert, 1996). Therefore, it is important to understand how best to empower households to save energy.

Energy saving behaviour does not occur in an unsystematic and random way. That is, some people save more energy than others, and some people may save energy more consistently than others. As such, energy behaviour is guided by antecedents that determine the individual differences in energy saving behaviour. It is important to understand the drivers of energy conservation as this will inform theory and policy makers on how energy conservation can best be stimulated. That is, by understanding why some people are more driven to save energy than other people, the various individual difference factors that affect energy behaviour will become apparent and provide an explain for what drives energy behaviour.

Various models have been designed and applied to predict energy use to account for these individual differences. These models and their application to energy use are reviewed in Chapter 2 and a model that not only includes motivational drivers, but also habitual and situational influences, seemed most promising in accounting for the antecedents of energy use. Therefore this model was tested using a mixed-methods approach in Chapters 3 and 4, and indeed the model was found to successfully apply to energy behaviour. Habits and situational influences were found to play a particularly important role in energy behaviour and may therefore be the most important antecedents of energy use. At that point, a key distinction is introduced into the discussion based on the work of Kempton, Harris, Keith, and Weihl (1985). It is suggested that, although these motivational, habitual and situational factors are likely to predict daily energy practices that involve *better management* (e.g. switching off devices that are not currently being used) and *curtailment of comfort* (e.g. reducing the temperature on the thermostat), these variables – especially habits – may not play such an important role for *efficiency investments* (e.g. purchasing energy saving light bulbs) or when householders consciously decide to take control of their energy use. Individual differences in these types of energy behaviours are more likely to be a result of people's conscious understanding of energy and how they consume it – in other words, their *energy literacy*. Indeed, energy literacy is highly likely to influence the decision making process when consumers intend to save energy. Hence, the second part of this thesis investigated that topic.

There is also a secondary reason for studying energy literacy. Models of the drivers of energy behaviour are not only limited in that they are unlikely to account for all types of energy behaviour, but they also tend to neglect the impact of the energy use. They predict the frequency of an energy saving behaviour, but do not factor in the effectiveness of the behaviour. Measures of energy use in psychology studies tend to rely on self-report measures and therefore often fail to reflect the true energy consumption of a person or a household. Instead, the actual energy savings are a result of the combination of the frequency of the energy saving behaviours and the impact of each particular behaviour. Therefore, models that aim to predict energy conservation are often limited in that they only predict the frequency of self-reported energy saving behaviours and the variables in the model may not adequately predict actual levels of energy conservation. That is, because these models fail to account for the impact of energy saving behaviour, these models may provide limited insight into how energy conservation is best stimulated (Gatersleben, Steg, & Vlek, 2002).

The impact of the energy conservation behaviour is dependent on the effectiveness of the energy saving behaviour performed by the householders. Moreover, whether a person saves energy effectively in their home is likely to be determined by their energy literacy. Specifically, if consumers have accurate knowledge of the energy consumption of their household devices, they will be able to focus their energy saving efforts on appliances that consume high levels of energy. Previous research has often assumed that a lack of knowledge about the total amount of energy that is consumed by households can explain a lack of energy conservation. Therefore, a great effort has been made to supply households with energy feedback, and the UK government has committed to a comprehensive roll-out scheme in which all households are offered a 'smart-meter', that permits real-time in-home displays with aggregated energy information (i.e. not appliance specific), by 2020 (DECC, 2015c). Although reviews of studies that have investigated the effect of feedback on energy use tend to view energy feedback as beneficial (Darby, 2006; Ehrhardt-martinez & Donnelly, 2010), it has been argued (Delmas, Fischlein, & Asensio, 2013) that the more robust studies only result in marginal energy savings (e.g. Bittle, Valesano, & Thaler, 1979; Brandon & Lewis, 1999; Hutton, Mauser, Filiatrault, & Ahtola, 1986), or may take time to influence behaviour (Murtagh et al., 2013), whereas other research shows that energy feedback is not effective at all (Katzev, Cooper, & Fisher, 1981), can increase electricity use in some cases (Bittle, Valesano, & Thaler, 1980; Brandon & Lewis, 1999), or may increase energy use when the feedback is withdrawn (Hayes & Cone, 1981).

It is likely that the lack of disaggregation of the energy feedback (i.e. energy use per appliance) leaves householders unsure which behaviours to change, but at the same time appliance specific energy feedback for each household device may be too overwhelming. As such, it is clear that a straightforward lack of feedback is not the key barrier to household energy conservation and alternative approaches to empower households to save energy effectively are needed. Therefore, and for the reasons set out above, the second part of this thesis will investigate people's understanding of the energy consumption in their home, with a focus on the energy use of their home appliances, and what cognitive factors affect this energy literacy.

By considering the antecedents of both energy behaviour and energy literacy in this thesis, a comprehensive account is provided of the factors that are most likely to influence curtailment as well as efficiency investment energy behaviours and this approach will ensure that the impact of the energy behaviours is considered as well. Consolidating these approaches, effective energy saving is a product of people being driven to save energy and their knowledge on how to save energy. This provides an interesting parallel with the health domain, where it has been generally assumed that behaviour change will only occur when people are both driven to change their behaviour and are knowledgeable about the health impact of the behaviour and alternative behaviours (Witte & Allen, 2000). Similarly, to save energy efficiently, both the drive and the knowledge on how to save energy needs to be present. A multiplicative model is proposed in which effective energy saving is a result of energy saving drivers as well as knowledge on how to save energy (see Figure 1). Specifically, householders should save the most energy when the individual is driven (be it by habits or motivations) to engage in daily energy curtailments behaviours *and* has the knowledge to make effective efficiency investments or select behaviours that will improve energy conservation practices. On the other hand, if an individual is not driven to save energy and does not know much about how to improve the energy efficiency in one's home, the lowest level of total energy conservation is anticipated. This is why this thesis therefore not only considers the drivers of energy conservation behaviour, but also the antecedents of energy literacy.

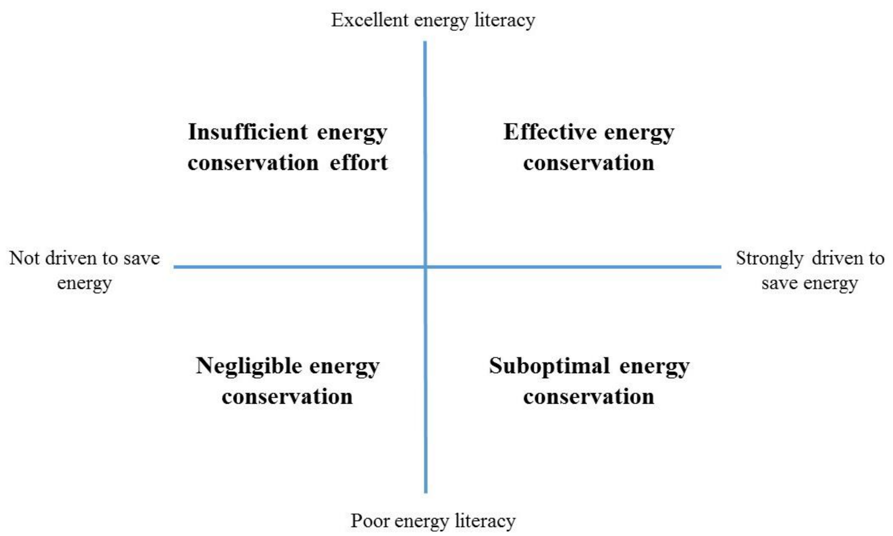

Figure 1: Multiplication model of energy literacy and energy saving drivers

This thesis therefore focuses on energy saving behaviour (or energy conservation), which is the reduction of a person's energy consumption. However, throughout this thesis energy behaviour (or energy use, energy consumption) will also be addressed when literature has only addressed the energy use of an individual, rather the reduction in energy use, or where otherwise appropriate.

1.1 Structure of the thesis

This thesis consists of nine chapters, of which seven can be divided in two broad areas of research: modelling the antecedents of energy behaviour and exploring the antecedents of energy literacy (which itself is also likely to be an antecedent of energy behaviour), corresponding to the energy saving drivers and energy literacy in the multiplication model proposed above. Furthermore, the studies within both areas of research follow a similar chronological process starting with background chapters, followed by exploratory work that fed into the investigative work, of which the results were applied and finally conclusions will be drawn. See Figure 2 for a schematic outline of this structure.

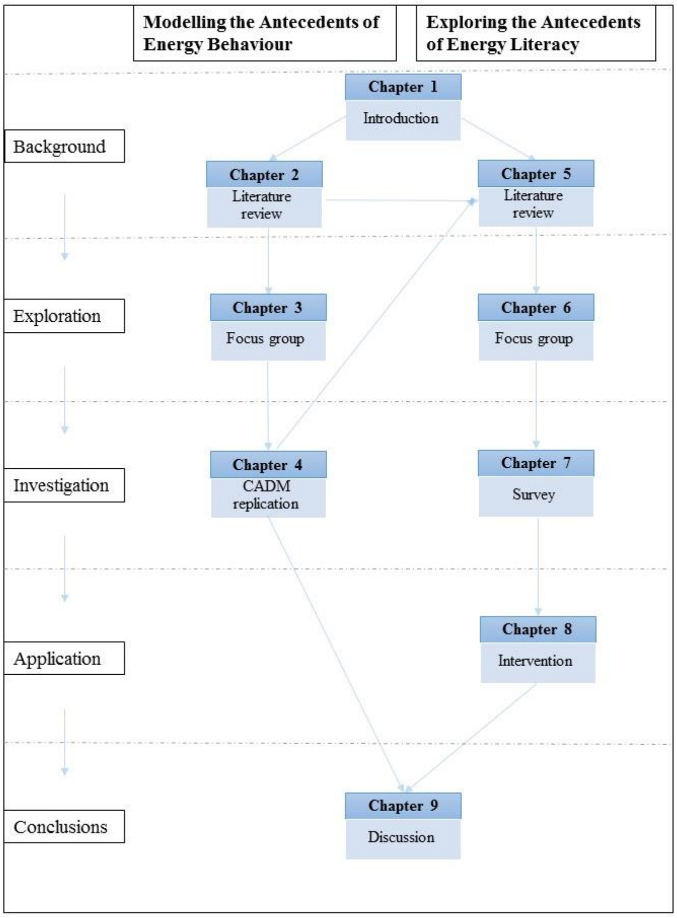

Figure 2: Schematic outline of the thesis

Note: CADM stands for Comprehensive Action Determination Model

1.1.1 Modelling energy behaviour

The background work in Chapter 2 consists of the literature review on energy behaviour models. A key conclusion from this review is that the recent Comprehensive Action Determination Model (CADM) seems particularly promising for understanding the antecedents of people's energy-related behaviours. The qualitative work in Chapter 3 then explores participants' views of the antecedents of their energy behaviour that will show to what extent people's perceptions of their energy behaviour matches the CADM and which other factors — that are not included in the CADM — they perceive to be relevant to their energy consumption. Chapter 4 further investigates the value of the CADM in relation to energy use by quantitatively testing the application of the model to predict energy behaviour, as well as an extended version of CADM based on the exploratory work in Chapter 3. These three chapters on energy behaviour modelling together provide a good account of the applicability of the CADM to energy behaviour, yet concludes by suggesting that this model does not address an important antecedent of energy conservation: people's understanding of energy consumption.

1.1.2 Exploring the antecedents of energy literacy

The second part of this thesis will therefore investigate people's understanding of energy consumption, or energy literacy. This section will similarly start with a literature review in Chapter 5 to evaluate the current literature on energy literacy and identify gaps within the research. Next, Chapter 6 reports on exploratory work in which participants' cognitive processes are observed when judging energy consumption in focus groups. This chapter aims to give an initial insight into these cognitive processes and forms the basis for the two studies to follow. People's awareness of the cognitive processes involved in energy judgements are further investigated in Chapter 7 using survey methodology. In Chapter 8, the findings of these studies are applied in an intervention study that aimed to alter the cognitive processes to enhance energy literacy in a real-world setting.

Finally, Chapter 9 summarises the findings and limitations of each study and integrates the findings from both sections of this thesis. General conclusions are drawn and the theoretical and policy implications of the findings are discussed.

1.2 Using mixed methods

This thesis will use a mixed methods approach that consists of a combination of quantitative and qualitative methods. Traditionally, these two approaches have been perceived as conflicting, as quantitative approaches involve statistical and experimental analysis and tend to take a positivist epistemology whereas qualitative methods focus on discursive and experiential analysis and traditionally rely on a constructive epistemology (Tashakkori & Teddlie, 2003). Therefore, this conflict between advocates of the two approaches, called the *incompatibility thesis*, implies that quantitative and qualitative methods are incompatible due to the conflicting underlying epistemology of the two approaches (Tashakkori & Teddlie, 2003). This issue might be resolved with the emergence of the *pragmatism and compatibility thesis,* in which a pragmatist position was proposed to counter the incompatibility thesis, meaning that the compatibility is accepted because 'it works' (Howe, 1988), and the foundation for mixed methods was thus developed (Tashakkori & Teddlie, 2003). Howe (1988) argued that quantitative and qualitative methods are compatible in practice and epistemology. As such, differences between quantitative and qualitative methods and findings stem from differences in research questions and the appropriate methods for these research questions. Moreover, he proposes a two-way relation between methods and paradigms where paradigms should not just determine the research methods (as the incompatibility thesis postulates), but research paradigms should also be selected on the basis of their merit in relation to the research methods and research questions. That is, this approach assumes that the researcher is free to combine methods if it benefits answering the research questions. Therefore, the methods for each study in this thesis will be based on the particular research questions and the particular paradigm of the methods will be chosen accordingly.

The use of mixed methods allows for *triangulation*: the combination of methods to study the same social phenomenon (Denzin, 1978). Some researchers argue that triangulation can serve to validate and verify results across different methods, for example by supplementing qualitative research by the application of statistical methods (Tashakkori & Teddlie, 2003). Agreement across the results of qualitative and quantitative research may indicate the validity of the findings meaning that the mixed-methods approach aids the internal and external validity of the results (Denzin, 1978). However, others have argued that convergence is not an indicator of the validity of the findings (Bryman, 1988; Hammersley & Atkinson, 1983), as even if the findings from two methods agree, they could both be "wrong in the same way" (Tashakkori & Teddlie, 2003, p.461). Hence, an alternative view has been proposed in which "Triangulation is less a strategy for validating results and procedures than an alternative to validation… which increases the scope, depth and consistency in methodological proceedings" (Flick, 1998, p.230). This is consistent with the view that quantitative and qualitative results can complement each other and therefore be used to supplement each other (Erzberger & Kelle, 2003). The use of mixed methods in this thesis therefore serves to both validate and confirm results and to increase the scope and consistency across different methods.

Mixed methods often follow certain cycles that can vary in induction, deduction and sequential or concurrent data collection. This thesis will use a *sequential Qual-Quant* approach that is characterised by using qualitative methods to generate theory, that is then tested using quantitative methods (Fine & Elsbach, 2000). A sequential Qual-Quant approach proposed by Cialdini (1980) is the *full-cycle* approach, in which research starts with real-world observations through qualitative methods, that are followed up by quantitative methods (e.g. lab experiments) and then loop back to real world applications through qualitative or quantitative methods. This cycle of research has been used to investigate donations to charity (Cialdini & Schroeder, 1976; Cialdini, Cacioppo, Bassett, & Miller, 1978), foot-in-the-door techniques in prison (Freedman & Fraser, 1966; Schein, 1956) and deindividuation (Zimbardo, 1969). This thesis will follow a similar approach as both parts start with explorative qualitative methods that generate hypotheses based on participants' experiences and observation that are then further investigated and tested using experimental design and other quantitative methods (see Figure 2). These empirical findings are then applied in the real world with a field study. The approach could be construed as a bottom-up, or inductive, approach as the observations in the real world inform theory development.

Furthermore, a post-positivist approach will be taken throughout this thesis to ensure consistency in epistemology across studies. This means the researcher's perception of the world is assumed to be closely related to the reality and the research in this thesis aims to uncover a *'singular truth'* (Braun & Clarke, 2013). However, unlike a pure positivist approach, the influence of the researcher's context on the research is acknowledged within the post-positivist approach (Braun & Clarke, 2013) and therefore the limitations of the objectivity of the data collection and interpretation will be highlighted where appropriate. This approach thereby differs from alternative epistemological stances that assume that the truth can change and knowledge is constructed through discourse systems of meaning (constructionism) or is a product of contexts and the researcher's position (contextualism) (Braun & Clarke, 2013).

Chapter 2: Reviewing Models and Theories on Energy Behaviour

In search of a model that can provide the best account of the antecedents of energy behaviour, this literature review will discuss and critically evaluate four families of models commonly used to explain energy or environmental behaviours. The model with most potential to explain energy behaviour was selected and taken forward. Literature relating each variable in this model to energy use was critically evaluated to investigate the relation of these variables with energy use and to test the applicability of the model to energy behaviour. In addition, alternative factors that were found to influence energy behaviour are discussed to provide a comprehensive account of the antecedents of energy behaviour.

2.1 Introduction

This literature review aimed to find a suitable model that can account for differences in energy behaviours across individuals. Although energy behaviour has received a lot of attention in the past few decades, there is no consensus on a most suitable energy behaviour model and different researchers advocate for the use of different models. In search of a model that can give the best account of the antecedents of energy behaviour, this review will discuss and critically evaluate models commonly used to explain energy or environmental behaviours. Four families of models will be reviewed: social interaction models, social cognition models, models including both social interaction and social cognition antecedents and models that extend the latter type by including external and habitual factors. Example models of these types will be discussed and the literature covering the application to energy or environmental behaviour will be reviewed. As such, key lessons from each model will be discussed and the literature will be synthesised rather than providing an exhaustive account of the research on these models. From this review, the model that is expected to be most successful in explaining and predicting energy behaviour was selected. The second part of this chapter will investigate the applicability of the model to energy behaviour for each variable in this model, literature that has investigated the effect of the variable on energy use will be discussed. To ensure a good coverage of the most important antecedents of energy behaviour, alternative factors that have consistently been demonstrated to be relevant to energy behaviour will also be discussed, whether or not they are included in the model.

2.2 Models and theories for energy behaviour

Psychology, and particularly the field of social cognition, has generated many models over the years in an attempt to explain the antecedents of behaviour. These models have been used in a wide variety of practical settings, including health behaviour, environmental behaviour and travel decisions, demonstrating how they attempt to provide neutral frameworks applicable to a range of behaviours. In search of a model that can account for the antecedents of energy behaviour, as well as to provide a framework for the various studies in this thesis, this section will discuss models and theories that have been designed or applied to energy behaviour or have the potential to relate to energy behaviour.

In the next few sections, the most important models are reviewed for their utility to explain energy behaviour. Models were selected to represent the wide range of theories that could apply to energy consumption, yet only models that could reasonably be assumed to apply to energy use were included. Where models have not yet been applied to energy use, literature that has applied the models to other environmental behaviours will be reviewed. It needs to be noted, however, that alternative environmental behaviours can differ from energy saving behaviours in various ways. Although most environmental behaviours are likely to be linked to moral processes (e.g. social norms), these behaviours may differ in the context in which the behaviours are performed, the frequency of the behaviours, the difficulty of the environmental behaviours as well as the impact of the behaviours. This means that if previous research has found that a model successfully predicts, for example, water consumption, this does not necessarily mean that the model will adequately account for the psychological processes that predict energy consumption. Therefore, the generalisability of this literature to energy behaviour will be carefully interpreted.

This literature review does not provide a full account of all the behavioural models that exist (for a more comprehensive review see Wilson & Dowlatabadi, 2007) but instead covers a sample of the different types of models existing in the literature. Furthermore, only models and theories that conceptualised behaviour on the individual level were included, thereby excluding sociological approaches that explore energy use on a household or societal level. The models are presented here in 'families' (social interaction models, social cognition models, etc.) to emphasise how several broad approaches aiming to explain behaviour can be seen in the multiplicity of models.

These groups of models will be discussed in order of their inclusiveness, starting with the most parsimonious models and reviewing increasingly comprehensive (and complex) theories and models. As such, the social interaction theories, which tend to limit their focus on specific aspects of behaviour will be discussed first. Second, socio-cognition models will be discussed, that not only consider characteristics that can predict behaviour but also account for the processes in which the individual differences influence behaviour. Third, the models and theories that include social interaction processes as well as individual differences will be critically reviewed. Finally, the most complex models will be discussed that consist of social interactions, individual differences and external and habitual factors.

2.2.1 Social interaction models

This section will investigate models that emphasise the importance of social interaction, and investigate how these social interactions affect behaviour. Examples of models that explore these interactions are the Family System Theory and the Self-Construal Theory. The central characteristics of these models are the individual differences regarding relationships with people in their environment, and how these individual differences can explain people's susceptibility to the influences of their social environment on their behaviour. These two models have been selected as good representations of this type of model because they cover the different contexts of social interaction adequately by focusing on a family level and a societal level.

2.2.1.1 Family System Theory

The Family System Theory (Bowen, 1993) assumes that a family is an emotional unit in which family members influence each other's emotions, thoughts and actions. A key concept in this theory is the differentiation of the self, which reflects a person's susceptibility to the influence of family members. Individuals with low levels of self-differentiation strongly depend on acceptance and approval of others whereas individuals with high levels of self-differentiation acknowledge their dependence on their family members, but when a conflict arises, these individuals are more likely to separate emotions from the conflict at hand.

No literature has been found that tested the application of this specific theory to energy consumption. This model generally suggests that behaviour is influenced by one's family and how strong this influence is differs across individuals. Research has demonstrated that, in line with this assumption, family members do strongly influence each other's environmental behaviour (Bratt, 1999). Moreover, parents set an example for their children to establish energy habits through parent-to-child behavioural modelling (McMakin, Malone, & Lundgren, 2002). Therefore, it seems likely that the concept of self-differentiation also applies to environmental behaviour, and energy behaviour specifically, meaning that one's susceptibility to the approval of the social environment determines to what extent an individual's pro-environmental behaviour is influenced by their social environment.

Many environmental behaviour models encompass the influence of the social environment with the inclusion of social norms. Social norms on energy use may be reflected in parental energy saving behaviour and parent's expressions of energy saving norms. However, research investigating how family members influence each other's energy behaviour is scarce (see section 2.3.1.1) and because it is likely that energy habits are established at a young age, and are therefore greatly influenced by family members, it is important that this is researched further.

2.2.1.2 Self-Construal Theory

This theory postulates that individuals in different cultures can hold different construals of themselves and of their environments (Markus & Kitayama, 1991). The theory distinguishes two types of self-construal: independent self-construal and interdependent self-construal. Independent self-construal is predominantly present in Western cultures and is characterized by the notion of distinctiveness among individuals (Markus et al., 1991). Individuals with independent self-construal tend to perceive themselves as autonomous, independent individuals and self-representations often reflect their characteristics, personality and attributions. Interdependent self-construal, on the other hand, is most common among non-western, collectivistic cultures that are marked by the connectedness among individuals. These individuals perceive themselves to be part of social relationships, feel less differentiated from each other and perceive their status as a participant in a greater social entity. Therefore, their self-image is characterised by their relationships with other people. The key notion of this model is that self-perceptions in relation to the environment influences behaviour.

This theory has successfully been applied to a range of environmental behaviours including recycling, green consumerism, transport behaviour and environmental activism (Arnocky, Stroink, & DeCicco, 2007). Independent self-construal was found to predict egoistic environmental concern (or egoistic values in the Value Belief Norm Theory, see section 2.2.3.3) and competitiveness over limited resources whereas interdependent self-construal predicted sharing of resources. Furthermore, a third type of construal, meta-personal self-construal, reflecting interconnectedness with other living things, was found to predict biospheric environmental concern (or biospheric values), cooperation over limited resources, and self-reported environmental behaviour (Arnocky et al., 2007). The notion of self-construal may also be relevant for energy behaviour in a way that people with interdependent self-construal or meta-personal self-construal might be more motivated to engage in energy conservation, although no research has yet explored this. Therefore, future research could explore if individual differences in self-construal can also predict differences in energy behaviour.

2.2.1.3 Conclusion on social interaction models

The social interactions theories outlined here highlight how people differ in their susceptibility of the influence of the social environment on their behaviour. The Family System Theory suggests that the influence of the social environment on behaviour is moderated by the type of self-differentiation the individual adheres to. The Self-Construal Theory, on the other hand, postulates that the relationship between the social environment and behaviour is moderated by the individual's self-construal. These theories do not necessarily conflict, as self-construal and self-differentiation might be closely related. That is, self-construal reflects how people distinguish themselves from their social environment in their perceptions of themselves, whereas self-differentiation relates to how susceptible an individual is to their social environment. These theories thereby complement each other as it is likely that people with interdependent self-construal or meta-personal self-construal have lower self-differentiation and are therefore more likely to adhere to social norms in their environment.

Most critically, although neither theory has so far been applied to energy use specifically, both make the common point that behaviour does not take place in isolation but rather takes place within a wider social context and is influenced by how a person views themselves with regard to that context. This is a principle likely to be important for sustainable behaviour such as energy use. People's level of self-construal and self-differentiation is also likely to affect the degree with which they are influenced by social norms on energy conservation in their social environment. Although the social interaction approach is therefore valuable in reminding us how the social environment influences behaviour, it is limited in its sole focus on social interactions as there are more factors besides the social environment that affect the energy use. Therefore, to gain a fuller understanding of energy behaviour, more social cognitive processes need to be taken into account.

2.2.2 Social cognition models and theories

This section will cover a mix of theories that endeavour to explain people's behaviour by focusing on social cognition processes. Social cognition constitutes the way people interpret, analyse, and process information about the social world (Baron, Brandscombe, & Byrne, 2008). These types of models and theories distinguish themselves from the social interaction models discussed above by solely focussing on social cognitive processes to account for behaviour rather than the interaction between individuals. As such, these types of models still consider the social environment, but do not require interaction with this social environment.

Typical social cognition models and theories that have been applied or have the potential to apply to environmental behaviour include the Knowledge Structure Model, the Goal Framing Theory, the Health Belief Model and the Self-Perception Theory. These models and theories are thought to adequately cover the range of existing social cognitive theories and models because they cover theories from cognitive, health and social psychology and thereby focus on various distinct individual differences within the family of social cognition models.

2.2.2.1 Knowledge Structure Model

Frick, Kaiser and Wilson (2004) proposed and validated a tripartite classification of environmental knowledge: *system knowledge, action-related knowledge* and *effectiveness knowledge*. System knowledge relates to knowledge about environmental problems and their causes. Action-related knowledge constitutes an individual's awareness of the available behavioural actions to mitigate these environmental problems. Finally, effectiveness knowledge entails the ability to judge environmental behaviours by their effectiveness in reducing environmental problems. Action-related knowledge and effectiveness knowledge have been found to directly predict conservation behaviour whereas system knowledge only influences behaviour indirectly through the other two types of environmental knowledge (Frick et al., 2004). However, action-related knowledge and effectiveness knowledge only explained 6% of variance in conservation behaviour including energy conservation, mobility and transportation, waste avoidance, consumerism and recycling (Frick et al., 2004). This clearly shows that a model only considering environmental knowledge fails to provide a full account of the antecedents of environmental behaviour.

2.2.2.2 Goal Framing Theory

According to Goal Framing Theory, goals guide information processing and behaviour (Lindenberg & Steg, 2007). Activated goals are believed to create a goal frame, meaning that one goal is salient whereas other goals are operating in the background. The theory identifies three types of goals: *hedonic goals, gain goals* and *normative goals.* A hedonic goal is a short-term goal to improve or maintain a positive affective state (e.g. pleasure/excitement seeking or avoiding effort/uncertainty) whereas gain goals aim to maintain or improve personal resources (e.g. saving money or increase income). Lindenberg and Steg (2007) argued that these two goal frames do not need strong cues to dominate information processing. Normative goals motivate individuals to behave appropriately according to social norms and need strong external cues to become a goal frame (Lindenberg & Steg, 2007). When background goals are compatible with the focal goal-frame, the background goals strengthen the focal goal frame. On the other hand, if focal goal-frame and background goals conflict, the background goals weaken the strength of the focal goal-frame (Steg & Vlek, 2009). As such, it has been proposed that the influence of the goal-frame can be addressed to stimulate environmental behaviour by increasing the relative weight of the normative or gain goal frame (as both goals can be achieved through energy consumption) compared to hedonic (which are likely to obstruct energy savings behaviour) (Steg & Vlek, 2009). For example, semantic primes (Liberman, Samuels, & Ross, 2004) and environmental cues (Bateson, Nettle, & Roberts, 2006) have been found to induce normative goal frames that result in normative behaviour.

This theory has been applied to energy consumption in the field of economics to extend microeconomic parameters that are often used to explain energy consumption (such as costs and effort) in this field (Oikonomou, Becchis, Steg & Russolillo, 2009). The authors found that normative goals are involved in energy conservation when individuals consider the moral aspects of energy consumption such as environmental quality and future generations as well as hedonic goals such as comfort and gain goals that relate to the costs of energy consumption. These goals therefore result in contrasting energy behavioural outcomes.

Considering the relevance of each type of goal to energy behaviour, this theory seems a promising framework to understand the conflicting goals in relation to energy consumption. Moreover, if goals that are congruent with energy conservation can be made salient by environmental cues (e.g. normative and gain), this would suggest a great opportunity to stimulate energy saving behaviour. However, no research has explored if environmental cues can enhance the relative salience of the normative or gain goal frame to stimulate energy conservation, or other environmental behaviours, leaving a clear gap in the literature.

2.2.2.3 Health Belief Model

This classic model was developed to explain people's engagement in health services (Rosenstock, 1966). The Health Belief Model consists of three parts: individual perceptions, modifying factors, and likelihood of action. The likelihood of taking action is influenced by the perceived balance of benefits and costs for behavioural change and the perceived threat of the particular disease. Both these factors are influenced by demographic factors such as sex, age, socio-economic status and knowledge. The perceived threat of the disease is additionally influenced by the perceived susceptibility to, and seriousness of, the disease and cues to action such as education, symptoms and media information. Later, the factor of self-efficacy was incorporated in the model to improve its predictive power (Rosenstock, Strecher, & Becker, 1988).

This model has been applied in the environmental domain by Linday and Strathman (1997) who used the model to predict recycling behaviour. The model was successful in explaining variance in recycling behaviour among participants (42%). The factors of the model that were successful in explaining recycling behaviour were perceived barriers, self-efficacy, awareness of consequences and likelihood of negative outcomes due to failure to recycle (which relates to the perceived susceptibility factor in the Health Belief Model). However, perceived benefits, knowledge of recycling procedures, severity of negative outcomes, norms, and demographics did not significantly predict recycling behaviour. Unfortunately, the model has not yet been applied to energy conservation, but considering that recycling, like energy use, occurs in a stable context, is performed frequently and is also related to environmental problems, it is likely that this model will also explain a good portion of variance in energy behaviour. As such, the literature in this section highlights how people's perceptions of their ability to act and the awareness of the consequences of not acting may be relevant to environmental behaviours.

2.2.2.4 Self-Perception Theory

This theory assumes that individuals cannot always rely on their internal state when inferring their own attitudes because these are often ambiguous or unclear (Bem, 1967). Therefore, when external causes do not explain the behaviour, individuals attribute internal causes for their behaviour and thereby infer their attitudes from their behaviour. Hence, this theory suggests that incentives for pro-environmental behaviour may be counter-productive because it may lead individuals to conclude that they do not adhere to environmental values but only conserve because of the rewards that are associated with the behaviour (Bolderdijk, Steg, Geller, Lehman, & Postmes, 2012). On the other hand, Self-Perception Theory predicts that when the behaviour is voluntary, individuals are more likely to infer a positive environmental identity from their environmental behaviour. Therefore, this positive environmental identity can result in the engagement in other pro-environmental behaviours, also known as a positive spill-over effect (Thøgersen, 1999). This theory differs from the previously discussed social interaction models as it does not consider social interactions, and solely focusses on individual cognitive processes whereby a person reflects on their own actions and motivations. Recycling has been found to have the potential to cause a positive spill-over into package waste prevention (Thøgersen, 1999) organic food consumption and the use of public transport (Thøgersen & Ölander, 2003) and these effects have been explained with the self-perception theory.

The spill-over effect has been investigated in relation to energy conservation in a study that provided participants with energy monitors (Hargreaves, Nye, & Burgess, 2010). Participants, who were mainly motivated to take part in the study to cut their carbon emissions, reported that their energy saving behaviour had spilled over into other environmental behaviours (reducing their driving, car-purchase, motivating their social environment to reduce their energy use). However, these findings may not generalise to the general population as the participants in this study were unlikely to have been representative of the population at large. That is, these participants were driven by environmental concern and energy conservation therefore boosted their environmental identity, a pre-requisite for the spill-over effect. People who are motivated to save energy for the financial incentives that are associated with energy conservation are unlikely to boost their environmental identity through energy saving behaviour which prevents a spill-over effect to other environmental behaviours. No studies have investigated the spill-over from other environmental behaviours into energy conservation behaviour, yet it is likely that when the engagement in other environmental behaviours foster a positive environmental identity, this can result in increased efforts to save energy.

2.2.2.5 Conclusion on social cognition models

These models and theories clearly show many of the social cognitive factors that can influence behaviour. The social cognitive approach to environmental behaviour seems to be successful in accounting for behavioural differences by considering the context of the situation that can influence the salience of goals (Goal Framing Theory), by focusing on individual differences in knowledge (Knowledge Structure Model), by considering perceptions of social aspects of behaviour (Health Belief Model), or a combination of context and interpretation processes (Self-Perception Theory).

The social cognition models differ in their ability to explain energy behaviour - where the goal framing theory was successfully applied, the knowledge structure model could only account for 6% of variation in different conservation behaviours. Although all of these models have their specific qualities by focusing on a particular aspect of the behaviour, they collectively are fragmented and do not provide a holistic view on energy use that can fully account for all the antecedents of energy behaviour. An integration of the discussed models would give a more accurate account of energy behaviour, yet, these would still be limited in their scope as they only consider social cognitive variables. Therefore, the next section will review models and theories that have taken this process a step further by integrating both social cognition and social interaction variables.

2.2.3 Models and theories integrating social interaction and social cognition variables

Models and theories that attempt to provide a more comprehensive account of behaviour than the models discussed so far consider both social interactions as well as social cognition processes. They are characterised by their schematic representation of the various processes that precede (energy) behaviour, in which the interaction between the variables is the central focus. Examples of these theories include the Theory of Planned Behaviour, the Norm Activation Model, the Value Belief Norm Theory and the Dual-process of Reactive and Intentional Decision Making, which will be discussed below. These models and theories have been selected as exemplars of this class of model because they have frequently been applied to environmental behaviour and energy consumption in particular. The following sections will critically review these models and theories and their application to energy consumption.

2.2.3.1 Theory of Planned behaviour

The Theory of Planned Behaviour (TPB) states that behaviour is determined by a behavioural intention which in turn is influenced by the attitude towards the behaviour (the positive or negative evaluation of the specific behaviour), the subjective norms (perceived social pressure to engage or refrain from the particular behaviour) and the perceived behavioural control (perceived ease with which the behaviour can be performed) (Ajzen, 1991). Applying this theory to energy behaviour, if a person has positive attitudes towards energy conservation, perceives social norms to engage in energy conservation and feels that energy conservation can be easily achieved, this model will predict strong intentions to save energy that will result in high levels of energy saving behaviour.

The model has been supported for a number of environmental behaviours such as recycling (Chu & Chiu, 2003) and car-use (Bamberg & Schmidt, 2003). However, this is the first model discussed so far that assumes behaviour follows from intentions which may not be a valid assumption for behaviour that involves less conscious processes, such as when behaviour is habitual. Habits are tendencies to repeat responses given a stable context (Ouellette & Wood, 1998) and have been demonstrated to be important predictors of various environmental behaviours such as choice of travel mode (Verplanken, Aarts, van Knippenberg, & Moonen, 1998), the purchase of organic food (Biel, Dahlstrand, & Grankvist, 2005) and, most importantly, energy use (Maréchal, 2010). These habits can create a so called intention-behaviour gap where intentions to engage in certain behaviours are not executed because strong habits can form a barrier. The TPB has therefore been found to be more successful in explaining behaviour involving high behavioural costs or constraints such as car use (Bamberg & Schmidt, 2003). Indeed, the variables in the TPB could only explain 2-5% of variance in household energy use (Abrahamse & Steg, 2011; Abrahamse & Steg, 2009) and 7% in self-reported household energy savings (Abrahamse & Steg, 2009). The key assumption of the TPB, that behaviour follows from intentions, may prevent have prevented a successful application of the model to energy use because energy use is likely to be influenced by habits.

2.2.3.2 Norm Activation Model

The Norm Activation Model (NAM) (Schwartz, 1977) holds that pro-environmental behaviour follows from the activation of personal norms which are feelings of moral obligation to engage in pro-environmental behaviour. According to the NAM, personal norms can be activated by the following factors: problem awareness (the level of awareness of the consequences of not activing environmentally), ascription of responsibility (feeling responsible for the consequences that result from environmentally harmful behaviour), outcome efficacy (identifications of behaviour that can alleviate the environmental problems) and self-efficacy (the recognition of one’s ability to mitigate these problems) (Schwartz, 1977).

The NAM has been demonstrated to be successful in explaining various types of pro-environmental intentions and behaviours such as willingness to pay for environmental protection (Guagnano, Dietz, & Stern, 1994) and energy conservation (Black, Stern, & Elworth, 1985). The latter study applied an extended version of the NAM, including demographic and economic factors (e.g. income, education, home ownership), which predicted concern for the energy situation, that in turn predicted the other NAM factors. Despite the inclusion of many relevant factors, the model could only account for 12% of variance in energy curtailment behaviour (Black, Stern, & Elworth, 1985).

In research by Abrahamse and Steg (2009), the addition of the NAM variables to the TPB variables did not improve the prediction of self-reported energy use. However, the NAM variables were able to predict 11% of self-reported energy saving behaviour, over and above the 7% that was predicted with the TPB variables (Abrahamse & Steg, 2009). In a similar study by the same authors (Abrahamse & Steg, 2011), NAM variables could account for observed energy use but not for self-reported intention to save energy, signalling a similar intention-behaviour gap as found with the TPB. Furthermore, the effect sizes for the NAM factors predicting personal norms (ascribed responsibility and awareness of consequences) varied between $.10 < r < .23$ and are thus considered small (Cohen, 1992).

Finally, a recent study tested the application of the NAM by operationalising the NAM factors specifically to energy use (Van Der Werff & Steg, 2015), unlike the previously discussed studies. The results showed that the model could still only account for 24% of variation in energy saving intentions, in line with the previously discussed studies which demonstrated the limited predictive power of the NAM for energy use. The literature on the NAM therefore suggests that energy behaviour may follow from (personal) norms, although the small effect sizes indicate that other factors may also play an important role.

2.2.3.3 Value Belief Norm Theory

The Value Belief Norm theory (VBN) (Stern, Dietz, Abel, Guagnano, & Kalof, 1999; Stern, 2000) is an extension of the NAM as it includes antecedents for the factors that predict personal norms. The VBN theory postulates that these factors depend on a person's ecological worldview (beliefs about the relationship between individuals and the environment) which in turn stems from the individual's values. The VBN includes three types of value dimensions: egoistic values, biospheric values and social altruistic values that represent a concern for the self, other living objects and other individuals respectively (Stern, 2000). This model closely relates to Self-Construal Theory (discussed in section 2.2.1.2), as research has found that self-construal could predict egoistic and biospheric values, suggesting that values may be tied to cultural differences (Arnocky et al., 2007). Furthermore, both self-construal and values have a broad influence over a wide range of behaviours rather than only affecting specific behaviours.

The model has successfully been applied to predict the acceptability of energy policies (Steg, Dreijerink, & Abrahamse, 2005). Furthermore, the application of the model to energy consumption has been tested in the aforementioned study by Abrahamse and Steg (2011), albeit using Schwartz' value dimensions (Schwartz, 1994) instead of Stern's. The model could significantly account for variance in actual energy use, but not for variance in the intention to reduce energy use, again demonstrating an intention-behaviour gap. Specifically, the value dimensions of tradition/security, power/achievement, and openness to change significantly predicted energy use. These findings support the inclusion of values into models to explain energy use.

2.2.3.4 The Dual-Process of Reactive and Intentional Decision Making

This model distinguishes between two types of decision making processes: the *reactive process* in which decision making is unintentional and based on situational factors, and the *intentional processes* in which goal-orientated intentions guide behaviour (Ohtomo & Hirose, 2007). The behavioural willingness to accept anti-environmental behaviour in the reactive decision making processes depends on the prototype image (the mental image of the typical person engaging in the behaviour) and descriptive norms (common behaviour). The behavioural intention, on the other hand, is dependent on the injunctive norm (perceived moral evaluation of the behaviour) and environmental concern. This model distinguishes itself from the previously discussed models by its inclusion of the perception of anti-environmental behaviour and unintentional factors, whereas other models have only considered perceptions of norms and attitudes of pro-environmental behaviour that predict behaviour intentions. The model was successfully applied to recycling behaviour (Ohtomo & Hirose, 2007) and various health behaviours (Gibbons, Houlihan, & Gerrard, 2009), but is yet to be applied to energy behaviours. It is likely that this model can be more successful in predicting energy use than the models discussed so far as it does not solely rely on intentions to predict behaviour and it considers people's prototype image of the typical person who saves energy to predict people's willingness to squander energy which may be a relevant predictor for energy use.

2.2.3.5 Conclusion on models and theories integrating social interaction and social cognition variables

The models and theories discussed in these sections seem to be more successful in explaining energy behaviour than the models and theories that solely included social cognition or social interaction variables. The models discussed in this section tend to include social interaction variables (e.g. normative processes) as well as social cognition variables (e.g. perceived control factors) and individual differences (e.g. attitudes) and thereby provide the most comprehensive account of energy consumption discussed so far. Studies that have tested these models of energy behaviour demonstrate that the NAM has incremental explanatory power over the TPB, presumably because of the inclusion of the additional normative variables. Furthermore, an application of the VBN to energy use showed that value-dimensions could also significantly predict energy use over and above the levels of a simpler model like TPB.

Nevertheless, a major limitation of these models is the assumption that behavioural intentions can adequately predict behaviour – that is, they assume that behaviour is always planned. However, this assumption does not seem to hold in the case of energy-saving intentions, due to the habitual nature of energy use. That is, when a person has positive attitudes towards energy conservation, perceives social pressure to save energy and feels that they can save energy and therefore has strong energy saving intentions, this does not necessarily mean that energy saving behaviour will be performed. This so called intention-behaviour gap has been found to represent as much as 46% of the sample for physical activity in a meta-analysis (Rhodes & De Bruijn, 2013). The magnitude of this gap highlights the limitations of relying on intentions to predict behaviour. Although the Dual-Process Model of Reactive and Intentional Decision Making does factor in unintentional processes, and may therefore have more predictive power than the other models, none of the models consider the habitual nature of (energy) behaviour. Given that recent research has begun to demonstrate the habitual nature of energy behaviour, the inclusion of habits in a model may bridge the intention-behaviour gap. The next and final section on energy models and theories will therefore evaluate the theories and models that account for the habitual nature of behaviour.

2.2.4 Models integrating social interaction, social-cognition, external and habitual factors

Although the previously discussed models tend to explain behaviour more parsimoniously, the final section of models that will be reviewed are models that may provide a fuller account of energy behaviour by also including external and habitual factors in addition to the social interaction and social cognition components. Few models are known to cover all these factors but examples include the Comprehensive Action Determination Model and the Motivation Ability Opportunity Model. The models combine all the factors from the integrative models (TPB, NAM etc.) that have been found to successfully explain environmental behaviour. Furthermore, these models are the first to include non-psychological factors such as the situational context of the behaviour. As behaviour always takes place in a certain context, and is therefore context dependent, these situational factors can have a great influence on behaviour. Moreover, by including such factors, the model does not solely rely on individual differences and thereby gives a more realistic account of the behaviour. These models have been selected as they are the only comprehensive models that have been applied to environmental behaviour.

2.2.4.1 *Comprehensive Action Determination Model*

This model attempts to integrate the TPB, the NAM and the Ipsative Theory (Klöckner & Blöbaum, 2010). The latter economics theory states that decision making is not only influenced by objective situational constraints and opportunities (objective possibility set), but also by contextual factors (the ipsative possibility set). The Comprehensive Action Determination Model (CADM) assumes that environmental behaviour is a result of a trade-off between habitual, intentional and situational processes. The habitual and intentional processes are in turn assumed to be influenced by normative processes. The normative processes consist of personal norms, social norms, awareness of consequences, and awareness of need. The habitual processes consist of heuristics, schemata and associations. The intentional processes include intentions and attitudes. Finally, the situational influences comprise of objective and subjective constraints.

These factors are assumed to interact and influence each other, and behaviour is therefore a product of the weights of the various factors. The various components are expected to differ in their influence on behaviour depending on the type of environmental behaviour. By integrating contextual factors with psychological factors, this model seeks to go beyond the previously discussed psychological models like the TPB and NAM and provides a more rounded, and perhaps more successful, explanation of behaviour. It thereby implicitly sees behaviour as the product of the person's conscious choices, their unconscious influences and also their environment. Bringing all these together is an interesting development and seems to be a promising avenue for the explanation of environmental behaviour.

The model was first applied (omitting the attitudes variable) to transportation mode choice and it was found to successfully explain 65% of variance in behaviour – an apparent improvement over traditional models such the TPB and NAM due to the inclusion of a greater range of behavioural influences than these models (Klöckner & Blöbaum, 2010). Although the model has not yet been applied to energy behaviour specifically, various versions of the model have been successfully applied to a range of sustainable behaviours. For example, the model was able to explain 44% of variance in general recycling behaviour and 68% of variance in recycling of specific items, although the objective control variable was omitted in this application (Klöckner & Oppedal, 2011). Furthermore, a version of the CADM that also included the New Environmental Paradigm (which reflects concern for the environment; Dunlap, Liere, Mertig, & Jones, 2000) was employed to predict the uptake of wood pellet heating and was found to explain 56% of variance in this behaviour (Sopha & Klöckner, 2011). Furthermore, the model was combined with the VBN (see section 2.2.3.3) in a meta-analytic structural equation model evaluation which included 56 studies that measured components of the CADM and VBN for various sustainable behaviours (including energy behaviour, waste behaviour, green tourism, meat consumption, car purchase and choice of electricity provider). The results showed an acceptable model fit, yet only 36% of variance in behaviour was explained in this model, whereas 55% of variance was explained in intention (Klöckner, 2013). This suggest that the inclusion of habits could not fully bridge the intention-behaviour gap, which may be due to the wide range of behaviours that were included in this meta-analysis, some of which may not be as habitual (e.g. green tourism). Specifically, the behaviours included consisted of both investment (e.g. car purchase) and curtailment behaviour (e.g. meat consumption), although investment behaviour is less likely to be of habitual nature because this type of behaviour may not occur frequently nor in stable contexts. Interestingly, the model has only been tested by the main author who first introduced the model, leaving room for confirmation bias, and the inconsistency in the model specification further suggest that this may be the case.

Because energy consumption has been found to depend on habits (Maréchal, 2010), this model is likely to apply to energy use. The inclusion of the relevant variables of the TPB and NAM, and especially the incorporation of habits and objective and subjective constraints in this model, makes it the most promising model to give a full account of energy behaviour discussed so far.

2.2.4.2 The Motivation Ability Opportunity model.

The Motivation Ability Opportunity model (MAOM) has been designed to aid the understanding of environmental consumer behaviour by borrowing the motivational component from the Theory of Reasoned Action (Fishbein, 1979) and incorporating the factors of ability and opportunity (Olander & Thøgerson, 1995). The motivational component includes beliefs, evaluations of outcomes, attitudes and social norms that predict intention (as is the case in the Theory of Reasoned Action). The relationship between intention and behaviour is then moderated by ability and opportunity.

The component of ability refers to one's capacity to carry out behavioural intentions and consists of two elements: habits and task knowledge, which differs from perceived behavioural control (as included in the TPB and CADM) as this factor does not include habits and reflects the subjective evaluation of task control. The translation of pro-environmental intentions into behaviour can fail if habits are not a routine (yet). Task knowledge reflects the awareness of the options to reach a certain goal. This model therefore implies that if people are not aware of what constitutes sustainable behaviour pro-environmental intentions may fail to be implemented (Olander & Thøgerson, 1995).

The component of opportunity in the MAOM is defined by Olander & Thøgerson (1995) as "objective preconditions for the behaviour" (p. 365), although the authors acknowledge that opportunities may be perceived differently across individuals. This concept closely relates to the objective and subjective constraints factors in the CADM as it considers the barriers and facilitators of the environment in which the behaviour is performed. Applying the component to energy behaviour, this factor reflects the objective ability to control energy consumption in one's home, for example, whether lights can be controlled in one's accommodation or whether these switch on and off automatically (as is often the case in student accommodation, for example).

This is the first specifically environmental model that has been proposed to incorporate the notion of habits, and is therefore similar to the CADM. The model has been illustrated using waste management, recycling behaviour (Olander & Thøgerson, 1995) and organic food purchase (Thøgersen, 2010), yet no studies have been found that have tested the predictive ability of the model in a systematic way using quantitative methods. Moreover, similar to the CADM, no studies have related this model to energy consumption.

2.2.4.3 Conclusion on Models integrating social interaction, social-cognition, external and habitual factors

These models seem to adequately cover the complexity of energy behaviour by including factors such as attitudes, social norms, intentions, habits, perceived behavioural control and situational conditions to predict environmental behaviour. The CADM and MAOM differ in that CADM organises its behavioural antecedents into normative processes, habitual processes and situational processes whereas the MAOM distinguishes between motivational, ability and opportunity processes. Nevertheless, closer inspection of these factors reveals that the normative, habitual and situational processes in the CADM closely resemble the motivational, ability and opportunity processes in the MAOM. The structure of the models are also similar in that the normative/motivational factors precede the intention although the models differ on whether the habitual/ability and situational/opportunity factors only mediate the relationship between intention and behaviour (MAOM) or also directly affect behaviour (CADM). It is more likely that habitual processes and situational factors both mediate the influence of intention on behaviour as well as directly affect behaviour, considering the strong influence habits and the environment can have on behaviour (Macey & Brown, 1983; Maréchal, 2010).

Both models include attitudes, habits, social norms, intention, objective constraints/opportunity and beliefs that may be similar to the awareness of need and awareness of consequences factors of the CADM. However, the CADM specifies the different types of normative processes that affect behaviour (personal norms and social norms) and explicitly operationalises beliefs into awareness of consequences and awareness of need. Furthermore, the habitual processes are a more focal point in the CADM because various habitual factors are included whereas the MAOM only considers habits and task knowledge.

Because the CADM is more detailed in its inclusion and description of its variables and also includes direct effects of habits and situational influences on behaviour, this model is more comprehensive than the MAOM and is therefore more likely to give a full account of energy behaviour.

2.2.5 Conclusion of models and theories on energy behaviour

The models discussed above not only differ in their ability to explain energy consumption but also differ in the (scope of the) behavioural aspects that are central to the models and their utility therefore depends on the context in which energy consumption is studied. For example, the social interaction models provide more detail about the transfer of norms and behaviour between individuals whereas the social cognition models give a fuller account of the cognitive processes that precede behaviour.

A clear pattern was shown in the review of these models: progressing through this review, the models that included more factors to explain energy were better able to predict energy behaviour accurately, while at the same time the models became less parsimonious. The models integrating social cognitive and social interaction variables connect the different aspects that affect behaviour and thereby better explain the interaction between the factors than models that only focus on either of these aspects. The comprehensive models discussed in the last sections may be the most promising to predict energy behaviour because of the incorporation of habitual and situational processes that are relevant to energy use. The CADM was found to be slightly more thorough then the MAOM and therefore this model will serve as a framework to contextualise and further aid the understanding of energy conservation.

2.3 Relating the CADM factors to energy behaviour

The last section reviewed models and theories that could be applied to explain energy behaviour. The Comprehensive Action Determination Model was found to cover the most relevant factors influencing energy behaviour and was therefore selected for further consideration (see Figure 3 for schematic representation of the model). Because no prior research has applied the model to energy use, the research that has explored the relation between each CADM factor and energy use will be reviewed in the next few sections. More specifically, literature will be reviewed to evaluate whether and how each factor is linked to energy consumption or energy saving behaviour to assess the applicability of this model to energy behaviour. When no studies have examined the relationship between the specific variable and energy behaviour, literature that relates the variable with alternative environmental behaviours will be discussed. Similar to the previous part of this chapter, this type of literature needs to be carefully interpreted for its generalisability to energy behaviour because these environmental behaviours may significantly differ in their antecedents. This review will thereby give a fuller understanding of energy behaviour and will review which of the CADM factors are relevant to explain energy use.

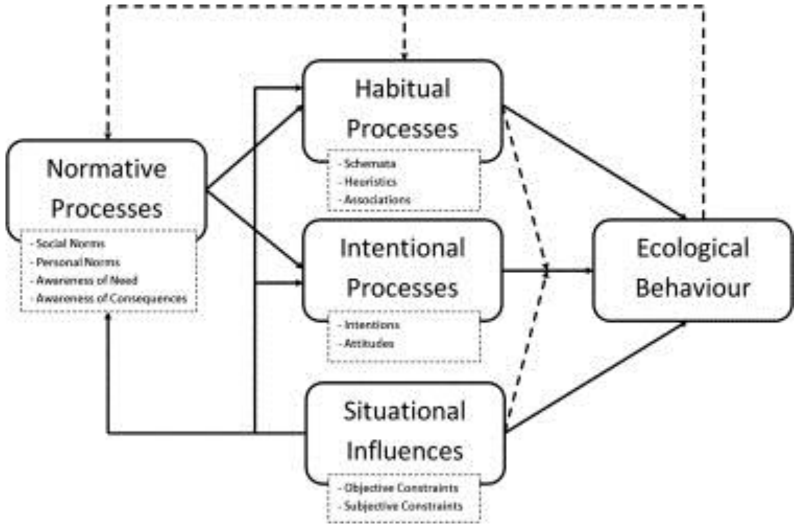

Figure 3: The Comprehensive Action Determination Model (Klöckner & Blöbaum, 2010)

2.3.1 Normative processes

The normative processes that are included in the CADM consist of social norms (originating from the TPB, see section 2.2.3.1), personal norms, awareness of need and awareness of consequences (borrowing from the NAM, see section 2.2.3.2). These variables share a focus on moral factors that can influence behaviour. In the following sections, each of these factors will be defined and literature on each factor in relation to energy behaviour will be discussed.

2.3.1.1 Social norms

Social norms constitute common or accepted beliefs concerning appropriate behaviour in a given context (Aarts & Dijksterhuis, 2003). Although this distinction has not been made in the CADM model, these social norms are commonly divided into *descriptive norms*, which comprise common behaviours, and *injunctive norms*, reflecting beliefs of what constitutes morally (dis)approved behaviour (Cialdini, Reno and Kallgren, 1990). The influence of social norms in the family as well as in society will be discussed in the following sections.

Various studies have demonstrated that perceived social norms affect energy conservation. For example, in a well-known study by Schultz, Nolan, Cialdini, Goldstein and Griskevicius (2007) households received descriptive normative information about their energy consumption relative to the energy consumption of similar households in their neighbourhood. This feedback resulted in a regression towards the mean in energy consumption: households consuming above average levels of energy decreased their energy use, whereas households that consumed below the mean, increased their energy consumption. This latter boomerang effect was eliminated when an injunctive message — reflecting social approval of energy conservation and disapproval of the increase of energy consumption through means of emoticons — was included in the feedback. Furthermore, people seem to be unaware of this influence of descriptive norms on their behaviour (Nolan, Schultz, Cialdini, Goldstein and Griskevicius, 2008).

The previously discussed study looked at the influence of perceived *societal norms* of energy use, whereas other studies have looked at the influence of perceived *family norms* of energy consumption. Studies show that parental attitudes and norms can determine adolescents' pro-environmental behaviour, in particular recycling behaviour (Matthies, 2012). Furthermore, parents have been found to influence their children's pro-environmental behaviour such as the purchase of green products, re-use of paper and recycling (Grønhøj & Thøgersen, 2009, 2012; Matthies, Selge, & Klöckner, 2012). However, weaker relations have been found between parental and children's energy conservation behaviour (Grønhøj & Thøgersen, 2009, 2012). This suggests that parental norms transfer to their children for some environmental behaviours but perhaps not for energy behaviour. The authors argued that energy behaviour does not transfer as effectively from parents to their offspring because the behaviour is less easy to observe by children, whereas this is not the case for the other types of environmental behaviour (Grønhøj & Thøgersen, 2012). Indeed, the child's electricity saving behaviour strongly correlated with how they perceived their parents energy saving behaviour (Grønhøj & Thøgersen, 2012). Alternatively, the weak correlation between parents' and children's' energy conservation may be attributed to the self-report measure of energy conservation which may not accurately reflect the energy saving behaviour. Parents may have more insight in their energy conservation as they are likely to engage in this behaviour more deliberately compared to their children who may not be aware of their energy curtailment habits resulting in an underestimation of their energy saving behaviour. Therefore, it is possible that norms about energy behaviour do transfer within the family and also influence energy conservation as was found for the perceived societal norms.

2.3.1.2 Personal norms

Personal norms constitute the feelings of personal moral obligation to engage in a specific behaviour (Schwartz, 1977). Research investigating the effect of personal norms towards energy conservation on energy behaviour has reported mixed findings. On the one hand, personal norms have been found to predict various energy curtailment behaviours including low cost efficiency improvements, home temperature, and major energy efficiency investments (Black et al., 1985). On the other hand, personal norms could not explain more variance than attitudes and perceived behavioural control in (direct and indirect) observed energy use and self-reported energy saving intentions (Abrahamse & Steg, 2011). Moreover, personal norms could not significantly predict self-reported energy use and energy savings in a similar study by Abrahamse and Steg (2009).

All of the measures in these studies of energy behaviour and energy savings consisted of self-reports except for the study by Abrahamse and Steg (2011) that measured energy use by observing meter readings *and* self-report. As energy consumption may be sensitive to social desirability, self-report measures may not accurately reflect true energy use which may have prevented a consistent relation between personal norms and energy use to show. This suggests that the findings by Abrahamse and Steg (2011) may be more reliable compared to the findings of Black and colleagues, and that personal norms do not predict energy use over and above attitudes and perceived behavioural control.

2.3.1.3 Awareness of need

Awareness of need, also labelled problem awareness in the NAM, has been defined as "the level of awareness of the adverse consequences of not acting pro-environmentally" (Steg, van den Berg, & de Groot, 2012, p. 157). Problem awareness has been demonstrated to influence a number of environmental behaviours such as car use (Nordlund & Garvill, 2003), chemical waste disposal (Stern et al., 1985) and various other environmental behaviours (Grob, 1995). However, this factor has often been excluded in applications of the NAM to energy behaviour (Abrahamse & Steg, 2011; Abrahamse & Steg, 2009) instead, the New Environmental Paradigm was measured which reflects concern for the environment (Dunlap et al., 2000). This variable alone could not significantly explain energy use or the intention to reduce energy use (Abrahamse & Steg, 2011). However, this scale was found to predict various energy behaviours such as replacing equipment, replacing light bulbs, turning down the heating and unplugging equipment currently not in use (Gatersleben, White, Abrahamse, Jackson, & Uzzell, 2010). Nevertheless, environmental concern differs from the awareness of need because one could be aware of the negative impact of behaviour on the environment but not be concerned about this. Therefore, these studies suggest that it is possible that the awareness of need influences energy behaviour, however, research is needed to test this hypothesis.

2.3.1.4 Awareness of consequences

This factor has been conceptualized as the belief that there is a causal relationship between one's actions and the negative consequences of the behaviour (Klöckner & Blöbaum, 2010). The effect of awareness of consequences of (direct and indirect) energy use and energy savings could not be demonstrated in the aforementioned study that applied the NAM to energy behaviour (Abrahamse & Steg, 2009). Furthermore, in a study testing the VBN,, awareness of consequences could not be proven to influence energy use and energy savings (Abrahamse & Steg, 2011). Moreover, a study that investigated people's beliefs about climate change found that beliefs about the reality of climate change was more predictive of pro-environmental behaviour (including energy conservation) compared to beliefs of the anthropogenic nature of climate change (Sibley & Kurz, 2013). This would therefore further suggest that people's awareness of the link between their actions and environmental problems is not one of the most important factors that predicts environmental behaviour. Although research outside of the domain of psychology has also found that people generally believe that conserving energy can help to solve energy problems, this positive attitude rarely translates into action (Dholakia, Dholakia, & Firat, 1983; Lutzenhiser, 1992). In short, previous research has not been able to demonstrate the link between awareness of consequences and energy behaviour.

2.3.1.5 Conclusion on normative processes

The literature that has investigated the relationship between the various variables that make up the normative processes with energy behaviour reports inconsistent findings. The influence of societal norms on energy behaviour has been well established whereas social norms in the family have not been proven to clearly affect energy behaviour. Research on the influence of personal norms on energy behaviour also does not reveal a consistent effect of these norms on behaviour. Although the relation between awareness of need and energy use remains understudied, perceptions of awareness of consequences has been studied in this context but could not be proven to affect energy behaviour.

This review therefore suggests that perhaps not all the normative processes included in the CADM are relevant for energy behaviour. Alternatively, these inconsistent findings may signal that the effect of these normative processes on energy intentions and behaviours are mediated by other factors, such as habit, perceived behavioural control and objective constraints, as proposed in the CADM. Furthermore, it needs to be noted that different measures and methodologies were used across the different studies which may prohibit consistent findings across the studies. Therefore, research is needed that measures the influence of all of these normative processes on energy consumption and energy savings using the same methodology.

2.3.2 Habitual processes

The component that is unique to the CADM and the MAOM compared to most environmental behaviour models is the habits component. Although in the original CADM model, habitual processes consisted of habits, schemata (or cognitive schemes), heuristics and associations, in each applications of the CADM, only the habit component has been tested (Klöckner, 2013; Klöckner & Blöbaum, 2010; Klöckner & Oppedal, 2011; Sopha & Klöckner, 2011).

Furthermore, few studies have been found to relate schemata, heuristics and associations directly to energy behaviour. However, various studies have looked at the role of heuristics in developing energy perceptions, which will become a focal point of the second part of this thesis (see Chapters 5-8). The following sections will only review literature that has explored the role of habits in energy behaviour.

Habits have been defined as: "learned sequences of acts that have become automatic responses to specific cues and are functional in obtaining certain goals or end states." (Verplanken & Aarts, 1999). Steg, van den Berg and de Groot (2012) ascribed the same characteristics to habits: they were said to be successful (i.e. functional), the context in which the behaviour is performed is stable (i.e. are responses to specific cues) and the behaviour does not involve a high level of involvement (i.e. are automatic). Furthermore, the authors extended this definition by noting that habits occur frequently (Steg, van den Berg & de Groot, 2012) .

Habits serve to save cognitive resources for other mental processes that require more cognitive effort (Faiers, Cook, & Neame, 2007; Wood, Quinn, & Kashy, 2002). Strong habits can prohibit intentions from being implemented (Maréchal, 2010; Verplanken & Faes, 1999). For example, habits moderate the impact of both intentions and personal norms on environmental behaviour (Klöckner & Matthies, 2004; Verplanken et al., 1998; Wood et al., 2002). Individuals with strong habits tend to be biased to attend to information that is congruent with their beliefs and behaviour (Maréchal, 2010). Furthermore, participants with strong habits view and use fewer pieces of alternative information in their decision making processes compared to participants with less strong habits, although this effect is attenuated when asking participants for a justification of their decision (Aarts, Verplanken, & van Knippenberg, 1997). These cognitive biases can therefore reinforce the habitual behaviour and make the behaviour difficult to change.

Energy use, like other environmental behaviour, is often of habitual nature (Maréchal, 2010). Indeed, Macey and Brown (1983) found that frequent energy behaviours were best predicted by past experience whereas infrequent energy behaviours were better predicted from intentions. Energy behaviour is likely to be of habitual nature because these three conditions for habits discussed above are satisfied for daily energy use: energy consumption is functional, often occurs in stable contexts (homes and work places), and can be performed automatically (Jackson, 2005). Moreover, energy behaviour is not necessarily perceived as complex behaviour, does not require a high level of involvement and is associated with a high degree of constraint (Maréchal, 2010). Whether energy consumers are aware of the habitual nature of their energy use remains unclear as underestimations of the influence of habits on energy consumption have been observed (Maréchal, 2010), whereas in another study participants were able to identify their energy habits in their interaction with household devices (Toth, Little, Read, Fitton, & Horton, 2013). As the awareness of habitual behaviour has been suggested to be key to changing the habits (Maréchal, 2010) it is important that this awareness will receive more research attention.

Besides the behaviour being automatic, another important condition for habits to develop is a stable context (Danner, Aarts, & de Vries, 2008). With this in mind, Verplanken and Wood, (2006) developed the *downstream-plus-context-change interventions*, a behavioural intervention targeted to change habitual behaviour, by linking the habits to life-changing events or contexts. These types of interventions have proven very successful for changing travel mode, especially among individuals with strong environmental concerns (Fujii & Gärling, 2003; Verplanken, Walker, Davis, & Jurasek, 2008; Walker, Thomas, & Verplanken, 2015). Maréchal (2010) has explored its utility in changing energy habits in a study in which individuals who had recently moved were more likely to request energy subsidies (for energy-efficient devices, the insulation of the house, etc.) compared to individuals who had not moved. However, one could question whether applying for energy subsidies classifies as habitual behaviour because it does not involve repetitive or automatic behaviour. More recently, an intervention aiming to stimulate sustainable behaviours (including energy saving behaviour) was found to be most successful among householders who had recently moved (Verplanken & Roy, 2016), which further underlines the importance of the role of habits in these types of behaviours.

Furthermore, it needs to be noted that it is likely that some energy behaviours may be more habitual than others. Specifically, curtailment behaviour (e.g. switching of lights) is more likely to be repeated frequently in the same context (e.g. home), whereas efficiency behaviour, such as installing double glazing, is less likely to be habitual because of the one-off nature and high investments of this behaviour. Nevertheless, this has not yet been confirmed in previous research on energy conservation behaviour. However, previous research has demonstrated that the strength of car habits are more predictive of willingness to curtail car use than the willingness to adopt eco-innovation technology (Jansson, Marell, & Nordlund, 2010).

In sum, energy behaviour is often habitual as it tends to be context dependent, automatic, and occurs frequently. This habitual nature of energy use can likely explain why people often fail to implement their energy saving intentions, as habits in relation to energy use moderate the relation between energy saving intentions and behaviours.

2.3.3 Situational influences

The situational influences consist of objective and subjective constraints on energy behaviour. That is, behaviour is contingent on its context because the environment can provide actual behavioural facilitators or barriers, or people's perception of the context may result in perceived facilitators or barriers. The literature on the influence of these two variables will be discussed in relation to energy behaviour in the next two sections.

2.3.3.1 Objective constraints

Although the psychological variables in the CADM are clearly important to environmental behaviour, a precondition of engaging in sustainable behaviour is that contextual variables allow or facilitate this behaviour. That is, there should be situational variables (Belk, 1975) (also referred to as facilitating conditions, Triandis, 1977 or objective preconditions Olander and Thøgerson, 1995) that facilitate or do not obstruct this behaviour. The importance of these contextual factors in pro-environmental behaviour has been demonstrated for recycling and waste-management (Olander & Thøgerson, 1995).

Three types of barriers have been proposed in relation to energy conservation: a lack of knowledge about energy conservation, low priority and high (financial and behavioural) costs of energy curtailment and inadequate availability of alternatives (e.g. energy efficient equipment) (Steg, 2008). Furthermore, the obstacles to energy conservation that were reported in a qualitative study corresponded to the above mentioned barriers and thereby validated the types of constraints (Semenza et al., 2008). Although knowledge and low prioritisation could also be interpreted as subjective constraints, the high financial cost of energy conservation and inadequate availability of alternatives are more evidently objective barriers that can prohibit energy saving behaviour. Although this research identified constraints relevant for energy conservation, the relationship between these factors and energy behaviour are yet to be confirmed by research. However, the influence of objective constraints has been established for other environmental behaviours such as littering behaviour. For example, a poll found that many respondents perceived littering as acceptable behaviour where insufficient bins are present (Lewis, Turton, & Sweetman, 2009), suggesting that objective constraints may influence the perception of injunctive norms

2.3.3.2 Subjective constraints

Subjective constraints also reflect factors that prohibit energy saving intentions from translating into actual energy curtailment, but differ from the objective constraints in that these potential obstacles may be perceived differently across individuals and therefore may not necessarily form a barrier for everyone. This concept is similar to the variable of perceived behavioural control in the theory of planned behaviour (Ajzen, 1991) which has been conceptualised as "people's perception of the ease or difficulty of performing the behaviour of interest" (p. 183). This TPB factor has been found to have the most predictive power for intention and behaviour compared to the models' other variables in a meta-analysis, although the study does not report what kind of behaviours were included in this analysis (Armitage & Conner, 2001).

Applications to energy use showed that perceived behavioural control could significantly predict the intention to save energy or energy saving behaviour but not current energy use (Abrahamse & Steg, 2009, 2011), which is likely due to the intention-behaviour gap previously discussed. In these studies, PBC items assessed participants' perception of their ability to save energy and mean scores showed that participants were neutral towards their ability to save energy.

The knowledge and prioritisation obstacles discussed in the former section may be important dimensions that underlie this perceived behavioural control (Steg, 2008). As such, when people are asked how easily they can save energy, it is likely that participants reflect on their knowledge to save energy and whether they feel that they are able to prioritise this behaviour over other constraints. The aforementioned Knowledge Structure Model identified three types of environmental knowledge and the concept of action knowledge and effectiveness knowledge closely resembles the conceptualisation of situational constraints as they reflect individuals' (perceptions of their) ability to save energy effectively. These types of knowledge could only explain 6 % of variance in various types of conservation behaviour. Furthermore, people's understanding of behaviour that mitigates global warming (effectiveness knowledge) has not been found to relate to the intention to alter the thermostatic settings to save energy (Truelove & Parks, 2012). However, beliefs about global warming mitigating behaviour (that were not necessarily true) were found to significantly predict the intention to change thermostatic settings (Truelove & Parks, 2012).

2.3.3.3 Conclusion

The previous sections showed that the research on the situational influences in the context of energy consumption is limited. Although some specific objective and subjective barriers have been proposed, their influence on energy behaviour has not been quantified. Studies that have related general perceptions of the ability to save energy to energy behaviour report inconsistent findings, meaning that these perceptions cannot always predict energy behaviour. Therefore, no firm conclusions can be drawn from this literature and more research on these barriers is required to explore the influence of these factors on energy behaviour.

The operationalisation of situational influences in the CADM does not include any aspects of knowledge towards the behaviour. Although the research on this type of knowledge does not show a consistent effect on conservation behaviour, it is very likely that people's (perception of their) knowledge on how to save energy will determine the influence of the situational variables. Therefore, future research would benefit from including people's (perception of their) knowledge on how to save energy to further investigate this relation. These types of knowledge will therefore be further investigated in relation to energy literacy in Chapters 5 to 8.

2.3.4 Intentional processes

The next two sections will describe the intentional processes that have been incorporated in the CADM. The variables that make up these processes are intentions and attitudes, borrowing from the TPB (see section 2.2.3.1). The following sections will assess how these variables have been found to relate to energy behaviour in previous research.

2.3.4.1 Attitudes

The CADM assumes that attitudes are directly related to behaviour, unlike the TPB that assumes that the influence of attitudes on behaviour is moderated by behavioural intentions. Attitudes have commonly been defined as a summary evaluation (whether positive, negative or neutral) of an object or event (Bohner & Wänke, 2002).

Four key dimensions have been identified that underlie attitudes towards energy consumption and conservation: high effort/pay-off ratio, the role of the consumer, the legitimacy of energy problems, thermal comfort and health (Becker, Seligman, Fazio, & Darley, 1981; Samuelson & Biek, 1991). Thermal comfort has consistently been found to be the strongest attitudinal predictor for energy conservation (Becker et al., 1981; Seligma et al., 1979; Samuelson & Biek, 1991; Tashchian, Slama, & Tashchian, 1984).

The majority of the research investigating how attitudes result in energy conservation has found a positive relation between the two variables. For example, a study that provided households with different types of feedback and information about energy consumption found that individuals with positive environmental attitudes were more likely to reduce their energy use after these interventions (Brandon & Lewis, 1999). This finding has been confirmed in recent research by Abrahamse and Steg (2011) who found that attitudes towards energy conservation could significantly account for energy saving practices. The positive relation between attitudes towards energy conservation and energy saving behaviour has also been confirmed for adolescents (Grønhøj & Thøgersen, 2012). However, in another study, attitudes towards energy problems did not correlate with self-reported energy curtailment activities except for individuals who expected to be personally affected by these energy problems (Olsen, 1981). This discrepancy may have arisen as the latter study measured attitudes towards energy problems whereas Brandon and Lewis (1999) and Abrahamse and Steg (2011) assessed attitudes towards behaviour. This is in line with the *Principle of Compatibility,* meaning that the relation between attitudes and behaviour is much stronger when attitudes are more specifically related to the behaviour (Fishbein & Ajzen, 1975).

2.3.4.2 Intentions

Many studies that explore energy conservation rely on measures of intentions to save energy as an indicator of energy curtailment behaviour, yet, the validity of this type of measure to predict actual behaviour has been widely questioned. Intention to engage in a particular behaviour has consistently been found to only moderately correlate (between $r = .44$ and $r = .52$) to actual behaviour (Armitage & Conner, 2001; Bamberg, 2002; Rhodes & De Bruijn, 2013; Sheeran & Orbell, 1998). Furthermore, Ouellette and Wood (1998) demonstrated that intention only predicts behaviour in situations characterised as difficult and unstable, leading individuals to make conscious decisions to engage in particular behaviour, which is unlikely to be the case for many daily energy behaviour. Because energy behaviour has been demonstrated to be driven by habits (see section 2.3.2), it is likely that this intention-behaviour gap also applies to intentions to save energy. Nevertheless, no study has directly tested the relationship between energy conservation intentions and behaviours as the studies that have tested models that include this link have either failed to include intentions to save energy (Abrahamse & Steg, 2009) or have not related intention to actual energy behaviour (Abrahamse & Steg, 2011). Therefore, it remains unclear whether energy conservation can be predicted from energy saving intentions.

2.3.4.3 Conclusion

The literature on attitudes shows inconsistent findings on the influence of attitudes on conservation behaviour. Although no research has investigated the link between energy saving intentions and behaviours, it is likely that the intention-behaviour gap identified in previous research also applies to energy saving intentions due to the habitual nature of energy behaviours.

2.3.5 Conclusion on factors of the CADM

The review of the literature on the relation between the CADM variables and energy consumption reveal a variety of findings. Therefore, no clear-cut answer can be given as to whether the model applies to energy behaviour. The application of the normative processes to energy behaviour resulted in mixed findings: whereas social norms clearly predicted energy behaviour, awareness of consequences did not, and the effect of personal norms and awareness of need on energy behaviour remained unclear. Contrary to the normative processes, the habitual processes have clearly been found to be involved in energy behaviour. Furthermore, situational influences were found to be understudied in the context of energy behaviour and the limited research to date does not show any consistent findings. Intentional processes may partly account for energy behaviour although this influence is not expected to be strong due to the influence of habits.

Various notes need to be made about the energy behaviour itself. First of all, energy conservation itself is not always consistent, for example teenagers tend to turn off lights, but not computers (DeWaters and Powers, 2011). Furthermore, most of the studies that have been discussed have measured energy behaviour using self-reported measures, assessing the frequency of energy (saving) behaviour, which may not reflect the true energy consumption. When only measuring the frequency of behaviour, the impact of the energy saving behaviour is not considered thus compromising the validity of the measurement (Gatersleben et al., 2002). Furthermore, this review suggests that some variables in the CADM (e.g. awareness of consequences) may not be as predictive of energy behaviour and therefore these variables may reduce the predictive power of the model. Finally, the inconsistency across and within each of the relations of the different CADM components with energy use clearly shows that more research is needed to truly assess the applicability of the model to energy behaviour. This inconsistency may be due to the variety of methods that have been used in the studies which makes a direct comparison problematic. Therefore, future research needs to include all of the CADM variables in one comprehensive study as this will increase the validity of these results and allows for the comparison of the relative influence of the variables on energy behaviour.

2.4 Alternative factors explaining energy use

The last sections evaluated the relation between the factors in the CADM to energy behaviour. The applicability of this model was shown to differ across the CADM antecedents. Although the CADM includes a large number of variables and thereby attempts to provide a complete and comprehensive account of environmental behaviour, there are various factors known to influence environmental behaviour that are not included in the model. That is, the concept of environmental identity and value-orientations seem to play a particularly important role in environmental behaviour and energy behaviour specifically. These factors have been discussed in relation to the Self-Perception Theory (see section 2.2.2.4) and the Value Belief Norm Theory (see section 2.2.3.3) respectively, in which their relevance to energy behaviour was highlighted. These antecedents of environmental behaviour are receiving increasingly more research attention in the last few years and their effect on the behaviour has consistently been demonstrated across a range of behaviours and contexts. Their exclusion from CADM could later prove to be an issue for that account. Therefore, the following sections will elaborate on these variables and their relation to energy consumption.

2.4.1 Values

Values are defined as one's guiding principles in life (Steg, van den Berg, & de Groot, 2012). The first value theory was proposed by Schwartz and Bilsky who distinguished four value dimensions forming a circumplex on which several values were projected (1990). The dimensions (and associated values) include: openness to change (stimulation, self-direction, hedonism) self-transcendence (universalism, benevolence), conservatism (conformity, tradition, security) and self-enhancement (especially the power and achievement, hedonism values). A study relating these dimensions to energy use found that the self-enhancement dimension (Power/Achievement values), the conservation dimension (Tradition/Security values) and the Openness to change dimension (Openness to change, Stimulation values) could significantly predict energy use (Abrahamse & Steg, 2011). However, only the latter value-dimension could predict individuals' intention to reduce energy use. Contradictory findings were reported in a different study investigating the role of self-enhancement and self-transcendent values that could not predict household energy use (Poortinga, Steg, & Vlek, 2004).

The Value Belief Norm model, described in section 2.2.3.3, includes similar value dimensions. Three types of values are distinguished, namely egoistic values, biospheric values and social altruistic values that represent a concern for the self, other living objects and other individuals respectively (Stern, Dietz, Abel, Guagnano, & Kalof, 1999; Stern, 2000). The egoistic values correspond to Schwartz's self-enhancement dimension whereas the biospheric values fit the self-transcendence dimension (Schultz, 2005).

These value dimensions have been related to a number of energy behaviours in a study by Gatersleben and colleagues (Gatersleben et al., 2010). Because biospheric and altruistic values were found to overlap, these were combined and together predicted the replacement of appliances, singing up for green tariffs, turning down the heating and unplugging equipment not in use, but did not predict self-reported energy conservation. Moreover, these value dimensions predicted the perceived importance of low-energy or energy conserving goods (such as solar panels, CF light bulbs), but not high energy consuming devices, suggesting that people with strong biospheric and altruistic values may be less attached to energy draining goods (Gatersleben et al., 2010).

Furthermore, research has shown how values may be indirectly related to energy use as they affect environmental identity (Gatersleben, Murtagh, & Abrahamse, 2012), awareness of consequences (De Groot, Steg, & Dicke, 2008; Nordlund & Garvill, 2002; 2003; Schultz, 2005; Steg, Dreijerink, & Abrahamse, 2005), attitudes towards nuclear and renewable energy sources (de Groot, Steg, & Poortinga, 2013; Perlaviciute & Steg, 2014), general environmental attitudes (Steg et al., 2005), ascription of responsibility (Steg et al., 2005) and, consistent with the NAM, activate personal norms (De Groot, Steg, & Dicke, 2008; Nordlund & Garvill, 2002; 2003; Steg, Dreijerink, & Abrahamse, 2005; Stern, Dietz, Abel, Guagnano, & Kalof, 1999).

All of this research demonstrates the relevance of values in relation to energy use but seems to suggest that the effect of values on energy use may be mediated by other variables. Research shows that values predict many of the current CADM factors, and therefore this literature review suggests that the CADM may be improved by including value-orientations.

2.4.2 Environmental Identity

Environmental identity has been defined as "the extent to which people indicate that environmentalism is a central part of who they are" (Steg, van den Berg, & de Groot, 2012, p. 141). This emergent concept has been found to aid the understanding of environmental behaviour. For example, people with a pro-environmental or green identity are more likely to engage in a range of sustainable behaviours including energy and water saving, pro-environmental transportation decisions, waste reduction, recycling, eco-consumption and avoiding flying to a holiday destination (Gatersleben, Murtagh, & Abrahamse, 2012; Whitmarsh & O'Neill, 2010). Moreover, the predictive power of environmental identity has been found to be stronger than the variables of the Theory of Planned Behaviour (Whitmarsh & O'Neill, 2010). Furthermore, Mannetti, Pierro and Livi (2004) demonstrated that individuals who perceived themselves to be similar to typical recyclers are more likely to engage in recycling behaviour compared to individuals who rate themselves as being different from recyclers. Environmental self-identity has also been found to mediate the relationship between values and pro-environmental preferences, intentions and behaviour (van der Werff, Steg, & Keizer, 2013). More importantly, an energy-saving self-identity could significantly account for the intention to save energy (van der Werff et al., 2013). People's environmental identity can be strengthened by making past environmental behaviour salient because people tend to infer their environmental identity from their behaviour, consistent with Self-Perception Theory (van der Werff et al., 2013). This stronger environmental identity can then cause a spill-over effect on to other environmental behaviours (Whitmarsh & O'Neill, 2010).

In short, the literature on environmental identity reveals the relevance of this concept in relation to environmental behaviour, including energy behaviour. The research also suggests that environmental identity can have a positive influence on stimulating environmental behaviours and this concept therefore seems to be a promising factor that needs to be included in future energy models.

2.4.3 Conclusion

The CADM includes many factors to account for environmental behaviour and is therefore the most comprehensive model that has been reviewed in this chapter. However, by only focusing on these factors in this model, other factors that have been found to be important in relation to energy use are overlooked. Values and environmental identity have often been researched in relation to energy use and their significance to explain energy behaviour has been confirmed in many studies. Therefore, it is likely that the inclusion of these variables can aid the successful application of the CADM to energy behaviour. However, research needs to confirm the superiority of these factors over the existing factors of the CADM with regard to energy behaviour.

2.5 Conclusion models on energy use

This literature review has thoroughly and critically investigated the literature on models and theories that have the potential to explain energy behaviour. The models that were more comprehensive were found to give a better account of environmental behaviour (and thereby possible energy behaviour) by integrating social cognitive and social interaction variables into the framework. Because energy behaviour is often of habitual nature and context dependent, the CADM seemed especially promising as it includes habitual and situational factors in the model. However, no research has tested the applicability of this model to energy behaviour and therefore literature on each CADM factor in relation to energy behaviour was explored. This review showed no consistent findings of the normative processes in the context of energy use, yet the role of habitual processes in energy use is well established. Furthermore, the literature remains unclear on what situational influences affect behaviour and more research is needed on this topic. Although attitudes towards energy conservation may partly predict energy behaviour, the intention-behaviour gap limits the explanatory power of the intentional processes of the CADM. Other factors that have been found to be relevant in relation to energy behaviour are values and environmental identity and models such as the CADM may therefore benefit from including these factors to give a better account of energy use. Therefore, this review calls for research that tests the applicability of each of the CADM factors to energy use and assesses if the CADM's ability to predict energy use can be enhanced by including environmental identity and values.

All of these models and factors in the models provide a good overview of the psychological factors that motivate energy use, yet these models fail to accurately reflect the impact of the behaviour. That is, these models and their antecedents predict the extent to which people are motivated to save or consume energy which is often measured using self-reported energy use in which participants report the frequency or range of conservation they engage in. Therefore, these models might predict that an individual is motivated to save energy and confirm high levels of energy conservation, even if an individual only engages in low-conservation impact behaviour. By neglecting to reflect on the impact of the behaviour, these models are limited in their ability to explain, predict and stimulate effective energy saving behaviour. This issue will be further discussed and addressed in Chapter 5.

Chapter 3: Exploring Perceptions of the Antecedents of Energy Behaviour

No behavioural model has been found to effectively account for the antecedents of energy behaviour, yet the literature review in Chapter 2 suggested that, of the models that do exist, the Comprehensive Action Determination Model (CADM) may be the most promising for explaining energy behaviour. Even here, however, the model has been built largely on quantitative research. The study reported in this chapter used a qualitative approach in which people's experiences and perceptions on their energy consumption was investigated to provide a more in-depth account of the suitability of the CADM compared to quantitative methods. Specifically, participants' perspectives on the antecedents of energy behaviour were investigated using focus groups. These perceptions were then mapped onto the CADM with a deductive thematic analysis to reveal the extent to which CADM concepts mapped onto people's view of the determinants of their energy use. The results supported the predictions of the CADM as participants frequently discussed social norms and perceived a strong influence of external motivators on their energy behaviour. Furthermore, a separate, inductive thematic analysis, allowed the identification of factors pertinent to people's perceptions of their energy behaviours that CADM does not include. This analysis showed the importance of value-orientation and environmental identity. This study suggests that the CADM is successful in predicting energy behaviour, which needs testing using quantitative methods in future research.

3.1 Introduction

The literature review in Chapter 2 highlighted the need for a model that adequately predicts energy behaviour. After an investigation of the literature relating various models to energy behaviour, the Comprehensive Action Determination Model (CADM) emerged as having the most potential to effectively account for energy behaviour. A review of the literature on the CADM variables showed that most of these factors are potentially relevant to energy behaviour, yet no studies have actually taken the step of relating the entire model to energy use specifically. This first study therefore aims to explore the applicability of the CADM to people's perception of their energy use. Specifically, participants' perceptions of the antecedents of their energy behaviour were compared to the antecedents in the model to examine the agreement between the two.

The CADM is a relatively new model (Klöckner & Blöbaum, 2010) that integrates factors of the Theory of Planned Behaviour (Ajzen, 1991), the Norm Activation Model (Schwartz, 1977) and the Ipsative theory (Tanner, 1999), see Figure 4. The CADM assumes that environmental behaviour is a result of a trade-off between habitual, intentional and situational processes. The habitual and intentional processes are in turn suggested to be influenced by normative processes. The normative processes consist of personal norms, social norms, awareness of consequences, and awareness of need. The habitual processes constitute of heuristics, schemata and associations. The intentional processes include intentions and attitudes. Finally the situational influences comprise of objective and subjective constraints. These variables interact and influence one another. Various versions of the model have been successful at predicting environmental behaviours; it could explain 65% of variance in transportation mode choice (Klöckner & Blöbaum, 2010), 44-68% of variance in recycling behaviour (Klöckner & Oppedal, 2011), and 56% of variance in adaptation of new heating systems (Sopha & Klöckner, 2011). However, the model could only account for 36% of variance when various environmental behaviours (including energy behaviour) were stacked together in a meta-analytic structural equation model evaluation (Klöckner, 2013).

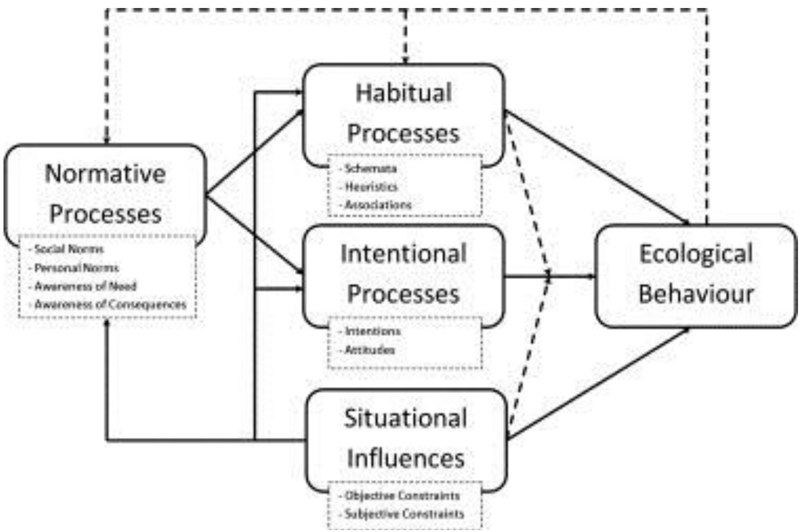

Figure 4: The Comprehensive Action Determination Model (Klöckner & Blöbaum, 2010)

Because no study has investigated the model in relation to energy use specifically, the literature review in the Chapter 2 considered how the CADM factors might be applied in that context. Studies that investigated factors that make up the normative processes have reported mixed findings on the influence of these antecedents on energy behaviour. For example, a strong effect of societal norms on energy behaviour has been found (Schultz et al., 2007), yet no clear effect of social norms in relation to energy use within the family has been reported (Grønhøj & Thøgersen, 2009, 2012). Furthermore, the literature remains inconclusive in regards to whether personal norms influence energy behaviour (Abrahamse & Steg, 2011; Abrahamse & Steg, 2009; Black et al., 1985). Although the relationship between awareness of need and energy use has not been investigated much, perceptions of awareness of consequences have been studied in this context but could not be proven to affect energy behaviour (Abrahamse & Steg, 2011; Abrahamse & Steg, 2009; Dholakia et al., 1983; Lutzenhiser, 1992). It is likely that the normative processes do not influence energy use directly, but their effect may be mediated by habits and intentions, as proposed in the CADM. Indeed, habits have consistently been found to be very relevant to energy use (Macey & Brown, 1983; Maréchal, 2010) as energy behaviour is context dependent, automatic, and frequent (Verplanken & Aarts, 1999).

Furthermore, habits may also account for the expected energy saving intention-behaviour gap. This intention-behaviour gap is anticipated based on the literature on other types of behaviour (Armitage & Conner, 2001; Bamberg, 2002; Brandon & Lewis, 1999; Rhodes & De Bruijn, 2013; Sheeran & Orbell, 1998). However, this gap has not been confirmed in relation to energy conservation in previous research. Strong evidence has been found for a direct relation between attitudes towards energy conservation and conservation behaviour (Abrahamse & Steg, 2011; Brandon & Lewis, 1999; Grønhøj & Thøgersen, 2012), a link that is unique to the CADM. Finally, the effect of situational influences on energy behaviour remains unclear as the literature on these factors is limited (Semenza et al., 2008; Steg, 2008; Truelove & Parks, 2012). Previous research therefore demonstrates inconsistent support for the relevance of each CADM factor in relation to energy use and thereby highlights the need for research that investigates this further.

The majority of the research discussed above has used quantitative methods to quantify the relations between these individual differences and behaviour. Instead, the current study will use a qualitative approach that allows for the description and characterisation of participants' perceptions of the CADM factors in relation to energy use. Qualitative methods complement quantitative methods as they can provide a different perspective on behaviour because it focuses on participants' experiences and perceptions and thereby provides different insights from quantitative methods (Silverman, 2011). These methods can thereby produce a deeper and more detailed understanding of the underlying factors and processes that influence behaviour and experiences (Silverman, 2013).

Furthermore, the CADM might not include all the factors that explain people's energy behaviour, meaning that important factors might be missing. This qualitative approach will also facilitate the exploration of factors influencing energy use that previous research might not have considered, as the quantitative approaches that were employed to developed and test the model is focused on measuring known ideas rather than identifying unknown ideas (Tashakkori & Teddlie, 2003).

Although previous qualitative research exploring perceptions of personal energy use is limited, qualitative research has proven to be successful in associated areas. To illustrate, Toth and colleagues (Toth et al., 2013) explored teenagers' attitudes towards energy consumption through diaries, stories and focus groups. The results of the thematic analysis showed how participants discussed the locations, sources of information, impact, barriers and concern in relation to energy saving. More importantly, some of the subthemes reported in this study overlapped with various CADM factors: energy habits, impact of energy use on the environment, future generations and costs (awareness of consequences), ways to save energy (subjective constraints), parents/media/school/peer influence (social norms), design of appliances (objective constraints) and views about saving energy (attitudes). The qualitative methods in this study therefore allowed for the identification of the topics teenagers find important in relation to energy use. This study will take a similar approach but will explicitly identify the CADM factors in participants' discussions of the antecedents of their energy use, rather than their attitudes.

Another qualitative study that was successful in investigating participants' perceptions on energy use interviewed participants about the importance of energy and water conservation as well as conservation policy (Kurz, Donaghue, Rapley, & Walker, 2005). This study showed how participants focused on the unsustainability of energy production rather than their personal consumption or managing demand, suggesting that they perceived a higher responsibility for policy makers to take action against climate change. These studies demonstrate how qualitative methods can provide a rich description of people's perceptions of energy use and therefore this study will extend the qualitative literature on people's energy perceptions.

3.1.1 Research aims

This study compared people's perspectives with the CADM and investigated if these perspectives suggest any factors that are not included in the CADM. Specifically, this study explored which (CADM) factors participants spontaneously discuss in relation to their energy use. The spontaneous discussions of the CADM factors showed participants' awareness of the influence of these factors on their energy behaviour. Moreover, it is possible that the relative frequency with which the factors were discussed reflected the perceived importance of the factors, although it is acknowledged that this may not necessarily be the case. Furthermore, this study explored which specific issues and topics participants raised in relation to each of these factors, with which it characterises and describes the perceptions of these factors. This will provide an insight into the relevance of the factors that influence energy use and thereby the application of the CADM to energy behaviour.

3.2 Methods

As discussed above, qualitative methods were more suitable then quantitative methods as the focus of the research in this study was on the participants' experience of their energy consumption. These methods allowed participants to raise any factors that they perceive to be relevant for their energy behaviour and a comparison could be drawn between participants' perspective and the CADM to evaluate how well their perceptions match the model.

Participants' perspectives on their energy behaviour was explored using focus groups, which involves a group discussion exploring a specific set of issues (Barbour & Kitzinger, 1999). This setting gave participants the freedom to discuss any factors that they perceived to be relevant to their energy behaviour as there was no fixed structure in which they were to express their experience. Focus groups are an excellent method to explore a wide range of views and perspectives (Underhill & Olmsted, 2003) and therefore facilitate the exploratory aims of this study. Unlike interviews, a focus group setting can facilitate discussions among participants in which participants are able to identify and explore points of disagreement and conformity (Underhill & Olmsted, 2003). This means that focus groups can stimulate the discussion of factors that may not have been considered in an individual interview. Furthermore, the social interaction in focus groups allowed for a more naturalistic way of discussing the topics compared to individual interviews that can encourage genuine expressions and views to be expressed (Silverman, 2013). It needs to be noted that the social interaction between participants in the focus groups was not of specific interest in this study, as the focus in this research was on the content of the discussions itself to investigate their congruence with the model. Therefore, the social context was not explicitly evaluated but will only be highlighted when directly relevant to the content of the discussions.

3.2.1 Ethical approval

Approval was granted by the University of Bath Department of Psychology ethics committee, reference number 12-156.

3.2.2 Participants

The questions about the antecedents of energy use were discussed in the second part of a focus group in which a rank-order task was conducted in the first part of the focus that is reported in Chapter 6. This second part, relevant for this study lasted between 15 and 20 minutes. Participants took part in one of seven focus groups that consisted of three to six participants. Participants (N = 26, age M = 18.93, SD = 1.09, 61 % female) were first-year undergraduates living on campus of the University of Bath. The recruitment was restricted to this sample because energy bills were included in their rent but these participants were expected to pay for their energy bills in the following year when they were to move into private accommodation and so their pre-move thoughts were of interest. Furthermore, these young people were of specific interest because they have recently become independent energy consumers, and were thereby likely to have been more reflective on their energy use. Participants were recruited through online (social media, online fora, noticeboards) and offline (posters) advertising and they were awarded course credit or a financial incentive (£5) for their participation. The advertisement did not mention the focus on environmental behaviour in the study, to avoid sampling bias. The majority of the sample consisted of British participants; five participants originated from other Western countries.

Due to the poor attendance at two of the scheduled focus groups, these were continued on as individual interviews. However, the data for these participants is not reported here because the findings suggested that the discussions significantly differed between focus groups and individual interviews.

3.2.3 Focus group procedure

The focus group started with the distribution of information sheet describing the nature of the research, the confidentiality of their discussions and their right to withdraw. Consent forms were signed by participants and the researcher. Participants were asked for a pseudonym that will be used in the references to the quotes to ensure confidentiality. After the rank-order task was completed (discussed in Chapter 6), participants were told the interview part of the session would commence and were encouraged to discuss the coming questions with each other and express any disagreements. Because social settings may prohibit shy participants from disagreeing with the group discussions (Barbour & Kitzinger, 1999), participants were urged to feel free to express deviant views or to disagree with each other. Furthermore, quiet participants were invited to contribute to the group discussion to make sure that their views were represented in the discussions as well and discussions were not just representative of a few dominant participants. To keep the participants focussed on the aim of the study, participants were encouraged to focus on discussing the questions that were asked when they seemed to dwell on unrelated issues (Braun & Clarke, 2013).

In the focus group sessions, participants were asked seven questions using a semi-structured method to prompt discussions and a range of perspectives on the antecedents of their energy behaviour. Interview questions covered topics such as changes in energy behaviour since moving into accommodation on the campus; the formation of energy behaviour; parental influence on the formation of energy behaviour; energy habits; flat energy rate versus metered based-rates; tips for future students who will live on campus regarding energy use and which factors, in relation to energy use, they might consider when selecting accommodation in the private sector for the next academic year. Some of these questions were directly related to specific factors in the CADM (e.g. "*Have you ever found yourself turning thing on and off without thinking about it?*") to ensure that these factors were discussed by the participants, whereas other questions were more general, and gave participants the freedom to discuss a range of antecedents of their energy behaviour (e.g. *Have you see any changes in your energy behaviour over the past year?"* or "*How have you learned your energy behaviour?*"). Furthermore participants were prompted to discuss their environmental identity specifically ("*Would you describe yourself as an environmental person?")* to explore participants perceptions and the relevance of this concept to energy behaviour. Care was taken on the part of the researcher to avoid introducing terminology or influencing the terms of the discussion (Arthur & Nazroo, 2003). The focus groups were recorded using audio recorders and transcribed verbatim in the NVivo data management program (QSR International Pty Ltd., 2012).

3.2.4 Analysis

The data was analysed using a hybrid approach consisting of a deductive thematic analysis and an inductive thematic analyses. The combination of a deductive and inductive analysis facilitated the research aims of this study as it allowed for the mapping of the CADM onto the discussions of the participants and facilitated the exploration of other relevant factors that are not included in the model. Furthermore, a great advantage of this approach is that it allowed the inspection of the discussions specific for each factor, rather than relying on the frequency with which the specific factors were discussed as is the case with content analysis (Silverman, 2013). A similar process of analysis was previously applied in a study on the role of performance feedback in the self-assessment of nursing practice, in which a combination of inductive and deductive thematic analysis was systematically applied to the data of focus groups and policies and procedures (Fereday, 2006).

Thematic analysis facilitates the identification of themes in the data that are relevant for the question at hand (Daly, Kellehear, & Gliksman, 1997). This type of analysis is conducted through a careful process involving the familiarisation with the data, the generation of initial codes, the search for themes, a review of the themes and defining the themes (Braun & Clarke, 2006). Familiarisation with the data was achieved through transcription and repeated listening to the recordings of the focus groups (Braun & Clarke, 2006). The rest of the steps of the analysis differed for the inductive and deductive thematic analysis and will therefore be discussed separately.

3.2.4.1 Deductive thematic analysis

First, the data was subjected to a deductive thematic analysis (or theoretical thematic analysis). In this type of analysis, the codes are theory-driven (Braun & Clarke, 2013) and therefore a coding matrix is constructed prior to the inspection of the data (Elo & Kyngäs, 2008). The deductive analysis involved the identification of discussions that related to each of the CADM factors and therefore the coding system was created based on the CADM, creating codes for each factor of the model. This is similar to the template approach, proposed by Crabtree and Miller (1999) in which a template (or codes) is defined and applied to the data after which the data is analysed. Discussions were only coded as such when they matched the definitions of each CADM factor (see Appendix A for definitions of each factor). When statements matched the definition of several factors, it was coded under each CADM variable to which the statement applied. Once the data was coded, the data for each code was analysed by examining how and what participants discussed in relation to each CADM factor. Furthermore, the discussions for each code was inspected for patterns. These patterns, as well as the frequency with which each factor was discussed by the participants, will be reported in the next section.

3.2.4.2 Inductive thematic analysis

Next, the data that did not fit the existing coding scheme was subjected to inductive thematic analysis. This facilitated the development of codes that could suggest additional factors to the CADM model. Inductive thematic analysis involves the development of categories based on the data rather than a pre-existing model (Braun & Clarke, 2006). New codes were developed for accounts that captured factors that were perceived to influence energy consumption, and the data was coded accordingly. The codes were then organised into themes that were consequently reviewed to ensure all coded data matched its respective theme and all the themes represent the data (Toth et al., 2013). Note that this coding process is likely to have been influenced and facilitated by the researcher's knowledge of the environmental psychology literature and the current trends and debates within this field of research.

3.2.4.3 Quality in qualitative research

Although it is acknowledged that the results of the analysis were dependent on the interpretation of the researcher, no test of inter-rater reliability was performed. Such tests aim to find consistency across researchers (Braun & Clarke, 2013), but does not focus on any particular differences in coding methods across researchers, and therefore does not help to illuminate the reasons for any coding discrepancies. In practice, disagreements in coding across researchers are often resolved through mutual concessions, although there is no consensus in the literature on how this agreement should be reached (Bryman& Burgess, 2002) nor is it clear if these revisions aid the quality of the analysis. Furthermore, inter-rater reliability tests require a large sample size (Yardley, 2008), which is not the case in this study.

The researcher's influence on the research processes and findings is inherent to qualitative methods and therefore scholars have argued that this type of analysis should not be expected to meet the same criteria of quantitative methods (such as reliability) (Braun, &

Clarke, 2013; Vidich & Lyman, 1994). That is, these terms such as reliability, validity and objectivity should be replaced with credibility, transferability, dependability and confirmability to better reflect the value of qualitative research (Denzin & Licoln, 1994). Indeed, inter-rater reliability checks are unusual in qualitative research, and are mainly conducted in studies in which the frequency of the codes are a focal part of the study, for example when content analysis is employed (Yardley, 2008). This study aimed to give an insight in people's perspectives of the influences on their energy behaviour, and as such did not focus on quantifying these perspectives. Although the frequencies with which CADM factors were observed to be discussed were inspected and considered, the relative instances were not taken to accurately represent the relative importance of these factors in the eyes of the participants.

Instead, to overcome these limitations, scholars have suggested that triangulation may be a better way to verify the findings, which is achieved when using a variety of methods (Armstrong, Gosling, Weinman, & Marteau, 1997). Indeed, using different methods is likely to provide different perspectives of the application of the CADM to energy use, and this is therefore believed to be a more valid approach than an inter-rater reliability test. Therefore the following chapter will discuss a study that has employed quantitative methods to further investigate the CADM in relation to energy.

3.3 Findings

The results of the deductive and inductive thematic analysis will be presented separately. The results of the deductive analysis will be structured in accordance with the structure of the CADM. The frequency with which each factor has been discussed by the participants is indicated in the title of the themes and these frequencies have been accumulated for the overarching processes in the model (e.g. normative, habitual, intentional), see Figure 5. The main topics discussed in relation to each variable will be reported within the group of processes of the model.

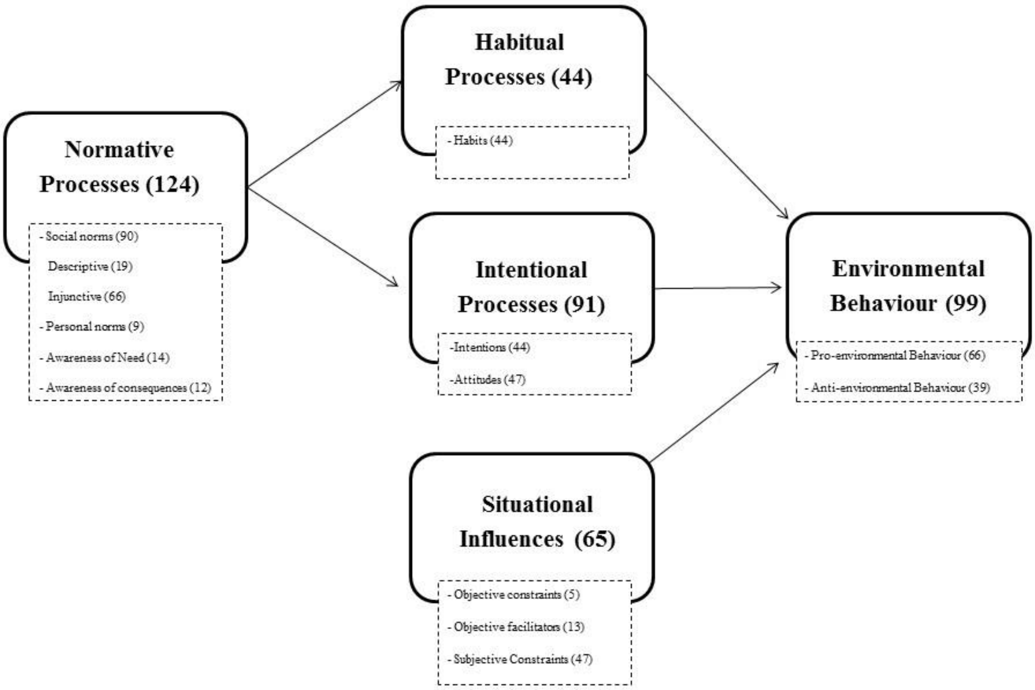

Figure 5: Results of the inductive thematic analysis mapped onto the CADM
Note: numerical values indicate the frequency with which participants discussed the factors

3.3.1 Normative Processes (124)

Most of the normative factors that the participants discussed could be coded as discussions on social norms, meaning the perceived social pressure to act in a certain way (Klöckner & Blöbaum, 2010). The other normative factors, personal norms (the perceived moral obligations to engage in particular pro-environmental actions Steg, Berg, & Groot, 2012), awareness of need (awareness of the adverse consequences of not acting pro-environmentally, Steg, Berg, & Groot, 2012) and awareness of consequences (the belief that one's own energy behaviour has negative environmental consequences, Abrahamse & Steg, 2011) were infrequently discussed.

3.3.1.1 Social norms (90)

This factor was divided into injunctive (67) and descriptive norms (23) to better specify the type of social norm involved. Injunctive norms consist of what most others approve or disapprove of (e.g. interventions/advertising/instructions from parents) whereas descriptive norms reflect what most others do (behaviour of parents/peers) (Cialdini et al., 1990).

Discussions of injunctive norms most often involved participants stating that they 'should' engage in more pro-environmental behaviour. For example, the following quote shows how a participant reflected on social norms in relation to leaving a television on standby and admits his behaviour is conflicting with this social norm:

"*TV is always on standby [others laugh], so... they say that you shouldn't do that."* (Steve)

Four different sources of injunctive norms were discussed by the participants. First, participants discussed energy saving behaviour being addressed in the media, thereby showing how injunctive norms are apparent in the media (8). For example, when participants were asked how they thought they had learned their energy behaviour, a participant responded:

"I'd say like, adverts and stuff, where they, I remember seeing loads of adverts, just reminding you to switch stuff off from stand by. I remember stuff like that." (Max)

A second type of injunctive norms discussed by participants was parental injunctive norms (20). Participants discussed how their parents expressed these norms, for example:

"*But I always switch off the lights when I leave my room uhm, because that's something my dad really insisted on*." (Jess)

It was evident, as demonstrated in the quote above, that participants perceived the energy use norms expressed by parents to influence their energy behaviour. Other participants also stated that they engaged in energy saving behaviour because of 'nagging' from parents, again reflecting injunctive social norms.

Third, injunctive norms expressed by peers were observed in the focus groups as participants told each other what they should or should not do (2). For example, in a discussion about the use of sleeping mode when not using a laptop instead of keeping the laptop in an active mode, a participant expressed his injunctive norm to the other participant:

"Oh, you should do that [all laugh quietly] and it doesn't use that much energy" (Max)

Finally, the participants discussed the injunctive norms expressed by their former school or current university (23). Participants discussed how these injunctive norms expressed by their school or university encouraged their energy saving behaviour:

"The university definitely promotes recycling and energy saving a lot, uhm, so I try to do, uhm, save energy, turn the lights off in my room when I'm not there and stuff," (Steve)

However, participants expressed that they perceived these injunctive norms not to be sufficient to induce energy saving behaviour because of a lack of incentives for energy conservation:

"I think it's strange here that there is no incentive to save energy, it sounds awful but I mean at home, there was this incentive from my parents." (Emma)

Furthermore, participants mentioned that the level of exposure (7) to injunctive norms influences the effect these norms have on their behaviour.

"*Yeah, I think the more you are reminded of, like, the issues [climate change], the more you uhm, try to do your bit."* (Alia)

That is, higher levels of exposure were perceived to have a more enduring effect on their pro-environmental behaviour. Moreover, the discussions suggested that climate change issues were not salient in people's minds in their daily life and that the exposure to injunctive norms reminded them of the importance of energy conservation and thereby encouraged this behaviour.

The descriptive norms that participants were observed to discussed mainly related to the energy behaviour of their parents (11) and peers (8). The discussions of the participants that described their parents' behaviour partly described their pro-environmental behaviour:

"My parents are extremely energy conscious because they are always trying to get the electricity bill down." (Emma)

This suggests that participants perceived their parents behaviour to be relevant to their behaviour and may therefore be shaped by these descriptive norms. However, several statements also described parents' lack of environmental behaviour:

"Yeah, like we didn't really, my parents didn't turn off the TV, so I just see it left on, like during the day, and be like, oh that's normal." (Minni)

In this quote, the participant explicitly states how the observation of her parents' behaviour shaped what she perceived to be 'normal' energy behaviour. The discussions of the transference of parents energy behaviour to their own behaviour suggests an implicit awareness of how descriptive norms might be internalised.

It was also evident that participants' viewed their housemates to be influential in their engagement in environmental behaviour:

"You can probably argue that, other houses, or other accommodation around, like for example, initially when you've come, you wouldn't have been as you might be now, but seeing that no one really bothers with it you are probably inclined to be like, you know what, I'm not gonna bother as well." (Jo)

As demonstrated in the quote above, the participant almost exclusively described a lack of environmental behaviour of his housemates, and how the observation of this behaviour reduced his own willingness to engage in pro-environmental behaviour himself, thereby clearly demonstrating the perceived influence of descriptive norms. However, in a few instances, participants talked about the pro-environmental behaviour of their peers and how observing this behaviour stimulated them to behave similarly:

> *"I have one flat-mate, he's like really energy conscious and stuff, and that will make you think about it more because they are obviously very determined and stuff."* (Lila)

Both of these quotes show how the observation of the energy behaviour of peers signalled social norms to which the participant tended to comply by aligning their energy use with that of their peers.

3.3.1.2 Personal norms (9)

A few times, participants were observed to discuss their moral obligations to engage in particular pro-environmental actions, thereby demonstrating their personal norms:

> *"I just try to use energy as efficiently as possible really, but I think, I think it's something you kind of have a responsibility to do as a human being."* (Sarah)

This quote shows how the participant perceived a strong sense of moral responsibility to engage in energy conservation. However, some discussions suggested that the participants had weak personal norms, as participants ascribed responsibility to mitigate environmental problems to other parties. For example, a participant expressed feeling that it was the responsibility of the people in power to take action:

> *"So it's up to the people at the top really, it's not our choice whether we want to go green or not. If we make ourselves happy, then yeah, fair enough, if you want to have solar panels and hydro-electric things in your garden, but it's a bit pointless, you're not going to be changing the world, it's only when the people at the top change it, then they'll change it."* (Jimmy)

3.3.1.3 Awareness of need (14)

Participants' awareness of need emerged when they discussed their knowledge of environmental problems:

> *"We did it in, uh, A2 biology as well, like, and I think it was this time last year, we did loads of stuff with energy use, like global warming, so I got a bit better then."* (Alia)

As demonstrated in the quote above, it was clear that participants thought that they had learnt about environmental problems through formal education, and that this stimulated their environmental behaviours. Moreover, participants also talked about learning about environmental problems through the media, but admitted that they were unsure if this knowledge resulted in energy conservation.

3.3.1.4 Awareness of consequences (12)

Although participants did not tend to explicitly state the environmental consequences of their own behaviour, their discussions did seem to suggest an awareness of the behaviour in indirect discussions of the consequences of behaviour. However, one participant did explicitly describe her awareness of the consequences of her behaviour which she learned in school:

> *"I think in school, I don't remember why, but in physics, I think, in particular because we did the electromagnetic spectrum, and quite a lot on electricity uhm, and the generation of electricity, they makes you quite aware of how much electricity you are actually using and like the processes by which the electricity is produced and how they are quite complex, obviously they use a lot of fuel to generate electricity in the first place and therefore, how it's a form of waste if you are not using this, uhm, the energy as efficiently as possible, and so then they tell you how to use the electricity as efficiently as possible."* (Sarah)

This quote clearly demonstrates how the participant is aware of the processes of energy production and the consequences of energy consumption for the environment. Moreover, it shows how the participants perceives to be motivated by this awareness to be mindful of the energy she uses.

3.3.2 Habitual Processes (44)

Habits have been defined as learned sequences of acts that have become automatic responses to specific cues and are functional in obtaining certain goals or end states (Verplanken & Aarts, 1999), and therefore discussions of habits were identified as participants' talk of automatic behaviours. Turning the light switches seemed to be the most salient example of habitual behaviour. Participants often emphasised the behaviour was 'automatic', 'a reflex', or performed 'without thinking about it'. Moreover, participants explicitly reflected on their energy habits:

> *"Yeah, rather more than I'm like, it's more habits than me, I don't make a conscious effort to be green I just carry on with the habits I already have. So I guess in that sense in my mind I'm not a really green person, but I guess my habits are pretty good."* (Hannah)

It was evident in participants discussions that they were aware of their energy habits, which is interesting considering that they explicitly reflected on the lack of consciousness that is involved in this behaviour. Moreover, the above quote also demonstrates how the participant discussed not feeling motivated to save energy for environmental reasons but energy saving habits were perceived to be the main driver of her behaviour. Some participants also talked about the intention to install an energy conservation habit, thereby further demonstrating the awareness of participants of the strong influence that energy habits can have on behaviour:

> *"Since I'm here, uhm, I noticed that you can, actually, turn off and on, the contact, the plug, and I can't do that in my country, so I've actually tried to do that, uhmm, but it's not really a habit yet."* (Emma)

3.3.3 Intentional processes (91)

Both intentional processes, intentions and attitudes, were frequently discussed by participants. Intentions were reflected in discussion of participants in which they expressed to plan to engage in pro-environmental behaviour and attitudes were reflected in discussions on the the positive or negative evaluation of the environmental behaviour (Bohner & Wänke, 2002).

3.3.3.1 Intentions (44)

Discussions within this element reflected intentions to engage in (more) pro-environmental behaviour, which mainly referred to energy-saving behaviour. These intentions often became apparent in participants' discussions in which they expressed to 'try' to save energy:

> *"I don't know, because it's still the process, I try to, but I'm not sure whether I manage to.*" (If)

However, this quote shows that the participant is not confident that the intention will result in behaviour and may expect not to succeed.

The majority of the talk in relation to pro-environmental intentions included a referral to the (lack of) financial incentives to save energy. That is, many of them argued that they would be more motivated to save energy if the university would install a metered rate for energy use or when the participants will pay their own energy bills when they are to move off campus in the next academic year:

> *"Yeah, also next year we'll have to pay for it, so I guess we'll be using less [others agree]"* (Jess)

Interestingly, a participant was found to justify her current excessive energy use with her intentions to save energy in the next academic year:

"But to be fair, next year, I won't be doing that because I'll be paying [others agree], so I'll make up for it." (Alia)

3.3.3.2 Attitudes (47)

The majority of participants expressed positive attitudes towards pro-environmental behaviour. Positive attitudes were evident in the use of adjectives for pro-environmental behaviour by participants:

"I never really recycled before, but you are encouraged to do that here, so that's quite good" (Steve)

The discussions suggest that these participants perceive pro-environmental behaviour, in particular energy conservation, as positive. However, some participants also appeared to have less favourable attitudes towards pro-environmental behaviour. For example:

"Uhm, I don't think of it in terms of, the environmental sort of thing, I just think do I need it? 1% yes, I can, then I just turn it on. It's not really, I have it so it's there, uhm, I don't want to go through the effort of, when I'm making dinner or something, have to turn everything on, like my laptop and everything, I just turn it on as soon as I get in, <u>or</u> I just leave it plugged in an walk out of the room to my lectures or whatever." (Jimmy)

This quote illustrates how some participants expressed a lack of interest in energy conservation and discussed not to be willing to exert effort to conserve energy.

Throughout the focus groups, the participants discussed their energy use, and the changes they had made in the last year. They consistently emphasised that these changes were not due to any changes in their attitudes, but rather a change of life style. This therefore suggests that although the discussions of participants showed that attitudes were relevant to energy conservation, participants did not seem to perceive a strong link between their attitudes and energy behaviour.

3.3.4 Situational Influences (65)

The CADM includes two types of situational influences in the model: subjective and objective constraints. Participants were more frequently observed to discuss the influence of subjective constraint on their energy behaviour, which reflects people's perception of the ease or difficulty of performing the behaviour of interest (Ajzen, 1991). Participants did not often discuss the objective constraints to influence their behaviour, which are factors that limit a person's freedom to engage in a particular behaviour. However, participants did discuss *facilitating* factors that encouraged their energy conservation and therefore a theme was created to include objective facilitators, in addition to objective constraints.

3.3.4.1 Objective Constraints (5)

Most of the talk coded under objective constraints related to factors that inhibit energy saving behaviour. One such example were the automatic lights in the common areas of the students' accommodation:

> *"When you step outside your room, depending on where you stand in the motion sensor, the lights off the entire house go on, so it doesn't always save energy, because you can't switch them off, it's just on for the next 5 minutes, and then they go off."* (Charlot)

This quote clearly illustrates how the participant perceived the automation of the lights to limit her ability to save energy. Further, another participant mentioned the energy inefficiency of the energy appliances, such as her oven and tumble dryer, in her student accommodation which restrained her energy saving.

3.3.4.2 Objective facilitators (13)

Participants not only mentioned objective constraints to save energy but also facilitating factors that help them to save energy. Interestingly, the automation of the lights in the accommodation were also discussed as facilitating energy saving:

> *"The lights in the (common) area go on automatically, so... you can't leave them on which is quite good"* (Steve)

Furthermore, participants discussed possessing few household appliances in their current accommodation, which facilitated energy saving as well as the naturally high temperature of their rooms.

3.3.4.3 Subjective Constraints (47)

Similar to Klöckner and Blöbaum (2010), this factor was interpreted as perceived behavioural control, meaning people's perception of the ease or difficulty of performing the behaviour of interest. Within their talk, participants expressed feeling that their energy saving behaviour would have an insignificant impact:

> *"But then I get, I find it especially frustrating at uni, with living with so many people and feeling so insignificant, like, in my window I can see like another 100 or 200 flats of other people just like me, and I just feel like any difference that I made will be counteracted by the people living in the same area"* (Emma)

Furthermore, participants articulated feeling limited in their ability to curtail energy consumption because of their perception of the necessity of the use of certain appliances such as a laptop.

Moreover, participants identified knowledge about energy saving to be a key influence in their perceived behavioural control. For example:

> *"No, literally, I have no advice to give, because I don't know how I could save more energy."* (Casper)

As demonstrated in the quote above, participants felt that a lack of knowledge about energy saving behaviour acted as a barrier to instigating energy saving behaviour. From the accounts of the participants, it appeared that knowledge about energy saving behaviours was key to their perceived control over their own energy saving behaviours. Furthermore, participants often questioned whether other individuals were knowledgeable about energy saving behaviour. Indeed, some statements suggested that the participants did not have perfect knowledge about the energy consumption of devices. For example, when discussing switching vacant plugs off, a participants stated:

> *"I'm like, maybe it is using energy without us realising."* (Emma)

Although the participant does not appear to be confident in her statement, this quote shows the participant's misperception about the energy use of a vacant plug, which is likely to limit the participant's ability to save energy.

3.3.5 Behaviour (99)

All the discussions about behaviour referred to environmental behaviour, meaning behaviour that has a positive or negative effect on the environment (Steg, van den Berg, & de Groot, 2012). Specifically, two-thirds of the discussions related to pro-environmental behaviour (behaviours that have a positive effect on the environment), whereas a third of the discussions concerned anti-environmental behaviour (behaviour that have a negative effect on the environment). Although participants discussed a wide range of different types of environmental behaviours, including water conservation and recycling, the majority of the discussions referred to energy behaviours because participants were asked about this behaviour specifically. Furthermore, all of the discussions involved (a lack of) better management (e.g. switching off devices that are not currently being used) and curtailment of comfort (e.g. reducing the temperature on the thermostat) behaviours, but efficiency investments (e.g. purchasing energy saving light bulbs) were not discussed.

3.3.5.1 Pro-environmental Behaviour (60)

Discussions about behaviour that has a positive (or less harmful) effect on the environment, mainly related to the curtailment or lack of use of household appliances:

> *"Iron: zero! I do not iron, ever."* (Hannah)

Moreover, some participants reported that since they had moved to campus they consumed less energy, and had reduced the use of certain household devices. Participants also reported a range of energy-saving activities, for example;

> "*So I will turn stuff off rather than let it on standby and turn off lights*." (Emma)

Other energy saving activities that the participants reported to engage in included minimising the amount of water that is heated in a kettle, putting on a jumper instead of turning on the heating, washing clothes less frequently and turning off the laptop when not in use.

3.3.5.2 Anti-environmental Behaviour (39)

Most of the discussions of anti-environmental behaviour consisted of participants expressing an increase in energy consumption since moving to campus:

> *"I reckon, I, like, use more energy in the kitchen because, I don't know, in our kitchen, we don't all share meals, so you're cooking like loads of separate meals, whereas at home you're cooking one thing for everyone"* (Alia)

Participants identified behaviours with which they had increased their impact on the environment since living in student accommodation. Specifically, participants identified which household devices they used more often since they had moved to campus, such as a laptop and the vacuum cleaner. The main reason for this increase in anti-environmental behaviour was the inclusion of their bills in their rent since moving to campus:

> *"I'm gonna be honest and say no, because everything is paid for, bills are paid for, so I just use it as much as I can."* (Jimmy)

3.3.6 Additional factors relevant to energy use

Thus far, the coverage here has looked at confirming themes that are included in the CADM, and participants' discussions certainly seem to confirm many of its predictions. The next two sections will discuss the results of the inductive thematic analysis, within this, elements additional to the CADM were identified. That is, discussions that did not match any of the CADM factors were coded into alternative codes using existing concepts in the literature within the field of environmental psychology.

3.3.6.1 Environmental identity (48)

Environmental identity has been defined as the extent to which people indicate that environmentalism is a central part of who they are (Gaterseleben & Steg, 2012). Participants identified themselves in relation to environmentalism both positively and negatively. That is, some participants did identify themselves as a green person, whereas others explicitly said they did not. Nevertheless, most participants were hesitant to claim that they perceived themselves as being a green person. Furthermore, several participants indicated that their environmental identity was fluid, as they thought that it had changed over the past year:

> *"If you consider, if you take out the year at uni where you got this piece of mind that you're not doing it [paying bills], otherwise I'd say I'm a green person, recycling, saving energy, partially because we have to pay for it, but that still, you know, helps me being green."* (Jo)

As is evident in this quote, participants discussed how their environmental identity had changed since they moved into university accommodation, mainly because of the lack of financial incentives. However, a 'green person' would not be expected to save energy because of the financial incentives, but rather out of a concern for the environment, suggesting that the participants were referring to the 'green' *behaviours* rather than their 'green' *identity*. Indeed, when participants were asked if they perceived themselves as a green person, many participants referred to their environmental behaviour:

> *"I'm green in the sense that I don't use a car, I walk most places."* (Emma)

These responses suggest that participants inferred their environmental identity from their environmental behaviour, rather than discussing how their environmental concern shapes their identity. Because the participants did not have financial motivators to save energy, participants may not have perceived external causes for their environmental behaviours, which may explain why participants inferred their environmental identity from their behaviours.

Furthermore, participants compared themselves to others to establish their environmental identity:

> *"Maybe in, like, comparison to the average person, I might be like, ok."*(Kevin)

This suggests the influence of social norms on the development of the participant's environmental identity, in which participants establish a norm of environmental identities in their social environment and compare their identity with this norm.

3.3.6.2 Value-orientation (82)

Throughout the discussions of their energy behaviour, participants' value-orientations became apparent, which are desirable goals that differ in their perceived importance (Steg, van den Berg, & de Groot, 2012). That is, the discussed factors influencing their behaviour often reflected their value-orientation (Steg et al., 2012). Although several value dimensions have been distinguished (de Groot & Thøgersen, 2012), only two types of value-orientations were identified in the participants' talk: biospheric values and egoistic values. Biospheric values reflect a concern for the quality of nature and the environment for its own sake, and egoistic values reflect a consideration for the self and personal benefit (de Groot & Thøgersen, 2012).

Egoistic values (71) were often identified in participants' discussions, and therefore appeared to be a salient factor for the participants. The majority of the discussions coded under this theme concerned participants saying they were only motivated to save energy for financial reasons, which suggested the influence of egoistic values:

> *"Maybe if I was paying for heat, I would, actually turn it down, [laughs], I don't know. Now it's always on maximum."* (Emma)

As with the participant above, many participants expressed not currently being concerned about energy saving because they were not paying for their energy bills. However, participants discussed expecting to start saving energy in the next academic year as this is when they would move into private accommodation and start paying for their energy bills:

> *"Yeah, also next year we'll have to pay for it, so I guess we'll be using less [others agree]"* (Jess)

Furthermore, participants justified their current high levels of energy consumption with the flat rate of their accommodation:

> *"I think, we are paying, I feel like we are paying so much for our accommodation [others agree] I feel like I need to have it as comfortable as I want and it needs to be value for money, so if I want it that temperature, I'll have it that temperature, if I want to have the lights on, I'll have the lights on."* (Emma)

The egoistic values are evident in these discussions as they suggest that participant's energy behaviour is mainly motivated by financial incentives, meaning their personal benefits. They expressed exploiting the current flat rate of energy consumption while living on campus, and therefore using high levels of energy. Furthermore, they expected to start conserving energy when they are going to be responsible for bills. This demonstrates how energy behaviour may be strongly motivated by concern for personal benefit, and is thereby driven by egoistic values.

Most of the responses recorded under biospheric values (9) were statements that reflected 'anti-biospheric' values, meaning that they reflected a lack of concern for the environment. For example, participants expressed not considering the environmental impact of their behaviour in their daily life:

> *"You're not gonna think: is the way I'm cooking it environmentally friendly? It would never cross my mind [others agree]"* (Hannah)

In this quote the participant expressed that her cooking practices are not driven by biospheric values.

The discussions coded under the value-orientation theme therefore suggest that participants expressed that their energy behaviour was strongly driven by their egoistic values, and they did not perceive biospheric values to guide their behaviour.

3.4 Discussion

This study aimed to explore people's perception of the antecedents of their energy use and to map these perceptions onto the CADM. In the next few sections, the outcomes of the deductive thematic analysis will be discussed for each group of processes as proposed by the CADM, and will be followed by a discussion of the findings of the inductive thematic analysis.

3.4.1 The application of the CADM to participants' perceptions of energy behaviour

The discussions of the participants that referred to the normative processes that affect their energy behaviour mainly covered social norms. Two-thirds of these discussions were categorised as injunctive norms, which primarily referred to their school and parental environment signalling that saving energy is 'the right thing to do'. This is in line with the aforementioned study that investigated teenagers' attitudes on energy behaviour in which participants also discussed parents, media, school and peers as sources of information on energy use (Toth et al., 2013). Moreover, participants rarely mentioned the link between energy consumption and environmental degradation (awareness of need) or the extent to which their own energy consumption has negative environmental consequences (awareness of consequences). Participants were also hardly observed to discuss their personal obligation to save energy (personal norms), which is in line with the aforementioned study by Kurz and colleagues in which participants mainly discussed responsibilities of politicians to reduce the negative consequences of energy use rather than their personal responsibility (Kurz et al., 2005). This suggests that the normative processes that are salient to the participants are primarily the social norms in their social environment, and not the consequences for the natural environment. These findings correspond rather well with the existing literature on the normative processes in the context of energy use (discussed in Chapter 2). That is, previous studies demonstrate strong support for the influence of social norms on energy behaviour (Schultz et al., 2007), whereas the effect of the other normative variables on behaviour remain unclear (Abrahamse & Steg, 2011; Abrahamse & Steg, 2009; Black et al., 1985).

Although these findings are in line with the influences on energy behaviour as found in previous research, Nolan and colleagues (Nolan et al., 2008) reported that participants did not acknowledge the influence of descriptive norms on their behaviour and were more willing to attribute their energy conservation behaviour to environmental conservation motivations. These findings are therefore incongruent with the findings of the current study in which participants acknowledged the role of descriptive norms on their energy behaviour. This discrepancy in the perceived determinant of behaviour may be because the study reported by Nolan and colleagues asked participants to attribute specific energy conservation behaviour to specific (descriptive norm or environment conservation) information, whereas the participants in the current study discussed influences of their social environment on general energy conservation behaviour. This therefore suggests that people may recognise the influence of their social environment on general energy behaviour, but may be less likely to ascribe specific energy behaviours to descriptive norms.

Energy saving habits were mentioned frequently by participants, in particular their tendency to switch off appliances (especially lights) automatically. The recurrent reference to habits in the discussions demonstrates the participants' awareness of these habits, which is surprising considering that habits are guided by automatic cognitive processes (Aarts, Verplanken, & Knippenberg, 1998). Nevertheless, participants have previously been found to be able to report on energy habits in the study by Toth and colleagues (Toth et al., 2013). Here participants referred to 'routines' and the lack of conscious decisions in their energy behaviour, similar to the current study. These findings therefore suggest that although most energy behaviour may be automatic and habitual, people may still be somewhat aware of their energy habits. Nevertheless, the influence of habits tend to be underestimated by householders (Maréchal, 2010). Indeed, only energy *saving* habits were discussed, not energy *consuming* habits, nor did participants explicitly note how their current habits can form a barrier for behavioural change.

Both energy intentions and attitudes towards energy consumption were found to be discussed repeatedly by participants. The discussions on intentions reflected aims to save energy. The discussions of these intentions were inherently connected to the discussion of one particular barrier that was perceived to prohibit the implementation to save energy: the lack of financial incentives to save energy. These discussions therefore suggest an intention-behaviour gap which is in line with previous literature discussed in Chapter 2 (Armitage & Conner, 2001; Bamberg, 2002; Rhodes & De Bruijn, 2013; Sheeran & Orbell, 1998). Participants primarily noted in these discussions that they intended to save more energy in the future when this barrier is removed. This therefore suggests a mediating role of situational influences on the relation between intention and behaviour, which is in line with the CADM. Furthermore, this highlights that the participants perceived a strong external motivation for their energy saving intentions and behaviour, rather than internal motivations. That is, these discussions suggest that participants were not motivated to save energy out of a concern for the environment and was therefore not driven by biospheric values (see discussion below on value-orientation).

The majority of the attitudes discussed, reflected positive attitudes towards energy conservation whereas some comments suggested negative attitudes. Moreover, the frequent expression of positive attitudes concerning energy conservation seems to contradict the importance of external motivators for energy saving behaviour, which were consistently emphasised by the participants. Moreover, attitudes on energy use were frequently brought up when participants discussed changes in their energy behaviour. That is, participants defended any changes in their energy consumption by emphasising that their (positive) attitudes towards saving energy had not changed. The positive energy-saving attitude in the context of knowingly not changing behaviour in the face of external barriers suggests that participants did not perceive consistency between their energy saving attitudes and their energy saving behaviour. This strongly contradicts the previous literature in which a robust link between energy saving attitudes and behaviour has been found (Abrahamse & Steg, 2011; Brandon & Lewis, 1999; Grønhøj & Thøgersen, 2012).

The majority of the situational influences that were discussed were categorised as subjective constraints, which included perceptions of the insignificance of their contributions when saving energy as well as their own, and other people's (lack of) knowledge about energy conservation. These barriers have also been identified in previous research (Semenza et al., 2008; Steg, 2008), however the influence of this perceived control on energy behaviour has not been confirmed (Abrahamse & Steg, 2011; Abrahamse & Steg, 2009). Participants discussed objective constraints and facilitators to save energy in relation to the facilities in their university accommodation. It needs to be noted that objective facilitators were not included in the situational processes in the CADM, but participants did perceive them to be important to their energy behaviour. The discussions on situational influences therefore show that participants perceived these contextual factors to be an important determinant of their energy behaviour.

Participants engaged in extensive discussions about their energy behaviour, in particular the change in energy behaviour since they had moved to campus. Two-thirds of the discussions related to energy saving behaviour and in particular a reduction in their energy consumption since moving into the university accommodation, whereas one-third of the discussion suggested a recent increase in energy consumption. These discussions thereby underline the role of situational influences on energy behaviour because participants report that the change in environment strongly affected their energy consumption patterns. Participants only discussed (a lack of) better management and curtailment of comfort behaviours, and failed to address efficiency investments (Kempton et al., 1985). The omission of efficiency investments from participants' discussions may be attributed to a lack of experience with these behaviours since these participants were unlikely to have encountered energy efficiency investments decisions such as installing loft insulation or even purchasing energy efficient light bulbs. Alternatively, these types of behaviours may have been less salient or not perceived as 'typical' energy saving behaviours. The exclusion of efficiency investment behaviours from participants' discussions implies that the findings in this study may only be relevant to better management and curtailment of comfort energy behaviours, and not efficiency investments behaviour.

The analysis of the participants' discussions of their energy use clearly shows that participants perceived the factors of the CADM to be relevant to their energy behaviour, which reflects positively on Klöckner's framework. However, some factors were discussed more frequently than others, suggesting that people might not perceive all of the CADM variables to be equally relevant to their energy behaviour. Inspecting the frequency with which the different variables were coded, the social norms variable clearly stood out, with 90 instances of participants referring to these influences. Other factors that were frequently discussed included energy habits, intentions, attitudes and subjective constraints. These factors relate to external motivators (social norms, habits, subjective constraints) and evaluations of energy behaviour (attitudes and intentions) itself. This suggests that participants were aware of the influence of these factors on their energy behaviour or perceived them as being important to their energy use. These factors might have also been more salient in relation to energy behaviour, meaning that they may have come to mind more easily, perhaps because they are more frequently discussed in relation to energy use in daily life.

The factors that were hardly mentioned by the participants included descriptive norms, personal norms, objective constraints, awareness of need and awareness of consequences. Interestingly, most of these variables refer to saving energy to mitigate environmental problems associated with energy consumption. This therefore suggests that participants did not perceive this to be a strong motivator of their energy conservation or participants may not be aware of these motivators of their energy use. This is in line with previous research that reported that young people tend to have weaker personal norms and therefore feel less responsible to engage in pro-environmental behaviour for the environment (Bator, et al., 2011; De Kort, McCalley, & Midden, 2008). However, the aforementioned study by Toth and colleagues (Toth et al., 2013) did find that participants discussed the environmental impact of energy consumption. Nevertheless, that study did not report how frequent participants discussed the environmental impact of energy consumption, nor did participants seem to discuss how this awareness influenced their behaviour and therefore it is not clear how important these factors were perceived to be by participants in this study (Toth et al., 2013).

In short, the findings of this study in relation to the CADM suggests that participants perceived external motivators, such as social norms, to be more important to their energy behaviour than environmental conservation.

3.4.2 Other factors relevant to energy behaviour

The discussions of the focus groups that did not match any of the CADM variables could be categorised into two themes: value-orientation and environmental identity. Throughout people’s discussions, their value-orientation tended to become apparent. The majority of the discussions reflected egoistic values, which was particularly present when participants discussed financial motivations to save energy. Participants repeatedly emphasised that they were currently not motivated to save energy because of an absence of a financial incentives, indicating the adherence to egoistic values. Furthermore, their intention to initiate energy-saving practices when this financial incentive would be introduced clearly signals egoistic values as this reflects a concern for personal benefit rather than the environment. Moreover, a few statements of participants referred to biospheric values, but these often reflected a lack of concern for the environment, thereby indicating weak biospheric values among participants.

These findings contradict previous literature in which participants tended to have stronger biospheric values compared to their egoistic values (de Groot & Steg, 2007; Gatersleben, White, Abrahamse, Jackson, & Uzzell, 2010). However, earlier studies tended to rely on self-report in surveys, which might explain the disparity in these findings. It is likely that both these methods are subject to social desirability but that the perceived social norms may be different across different methods because the relevant social group differs. That is, in survey studies, a societal norm may be most salient because other participants may reasonably be expected to be other members of the society. The focus group, on the other hand consisted of fellow campus residents, and therefore social norms in a student population may have dominated the discussions. Previous research has not been able to confirm the link between egoistic values and energy use (Gatersleben et al., 2010; Poortinga, Steg, & Vlek, 2004), although biospheric and altruistic values have been found to be positively associated with energy saving behaviours such as unplugging appliances that are not in use and reducing the thermostat (Gatersleben et al., 2010).

However, the self-enhancement dimension in Schwartz' value theory (Schwartz & Bilsky, 1990), which corresponds to egoistic value orientations, has been found to be predictive of energy use (Abrahamse & Steg, 2011). Furthermore, the strong influence of financial incentives on energy consumption has consistently been confirmed in previous research (for a review see Guerin, Yust, & Coopet, 2000), and was also identified in the aforementioned study by Toth and colleagues (Toth et al., 2013). Previous research therefore provides mixed findings on the influence of values on energy use and therefore more research is needed to confirm this link.

Unlike the value-orientation variable, the environmental identity factor arose as participants were prompted to discuss their environmental identity. Both positive and negative environmental identities were discussed, although the majority of the discussions covered positive environmental identities. These identities were established by participants by referring to their past environmental behaviour or through social comparison. This is consistent with Self-Perception Theory, discussed in section 2.2.2.4, the previous chapter, which postulates that people tend to infer their attitudes and identities from their behaviour when they do not perceive any strong external causes for their behaviours (Bem, 1967). This therefore suggests that environmental identities in relation to energy behaviour may result into a spill-over effect into other environmental behaviours when financial incentives are not present, as discussed in Chapter 2. Although participants did not discuss that their environmental identity caused their energy behaviour, previous research has found that environmental identities can predict (intentions of) energy conservation (Gatersleben et al., 2012; van der Werff et al., 2013; Whitmarsh & O'Neill, 2010), although this may be due to the inference of the identity from behaviour.

In sum, this study shows how value-orientation (especially egoistic values) and environmental identity are relevant to energy behaviour and may be able to predict energy behaviour. These factors are currently not included in the CADM and may therefore be a valuable addition to the CADM.

3.4.3 Methodological considerations

This study presents a wealth of findings and perspectives on participants' views of their energy use. The qualitative approach that was employed has facilitated the research aims of this study, and the many advantages of this methodology have been discussed in section 3.2. However, it needs to be noted that these findings need to be interpreted in light of a few methodological concerns. First, the perceptions of the influences on energy behaviour found in this study may be specific to the characteristics of the sample which consisted of students living in university accommodation. A key difference between these individuals and the general population is that they do not pay for their electricity consumption. This is likely to have affected their perceptions of their energy use and in particular the discussion of the motivators to save energy. Therefore this study provides a unique insight into people's perception of their energy use when they do not experience financial incentives to save energy. One of the main findings in this study is that the participants strongly emphasised that their energy behaviour was motivated by financial incentives. As this financial incentive to save energy was absent at the time of the study for participants, and many participants may not have had this incentive in the past (as many students have moved from their parental homes), their perception on the influence of this incentive may not have been accurate and participants may have overestimated the influence of it. Alternatively, this sample may have been very aware of the influence of financial motivators on their behaviour, as they kept emphasising that they anticipated a change in their energy behaviour when their energy behaviour will have financial consequences.

As discussed above, participants' discussions may not necessarily reflect the true perceptions of their energy behaviour due to the social context of the focus group. The social influence of the group is likely to have influenced which topics participants raised and the way that they discussed these topics (Braun & Clarke, 2013). This means that the influences of some factors may have been downplayed or not discussed at all because participants may not have been comfortable with discussing the topic (Barbour & Kitzinger, 1999), whereas the influences of other factors may have been overstated. Furthermore, participants may have been influenced by the dynamics of the focus group where more submissive participants may have shown agreement with more leading participants in the discussions, which may not be true to their own views (Barbour & Kitzinger, 1999). Although these social factors were not considered in the analysis, it is important to bear in mind that they may have influenced the findings of the study. That is, if participants did not feel comfortable to display divergent views, a more homogenous view of the antecedents of energy use may have been observed in the focus group than was accurate, due to the social dynamics of the focus groups.

Second, the researcher's role in the data analysis process needs to be acknowledged. The researcher's knowledge of the environmental psychology literature is likely to have strongly influenced the coding of the data. In the deductive stage of the thematic analysis, the familiarity of the researcher with the concepts in this model facilitated the coding process as it means that the researcher was adequately skilled in identifying these concepts in every-day discussions. However, in the inductive stage of the analysis, the researcher's background may have resulted in the identification of concepts that the researcher was more familiar with or that are trending in the environmental psychology community. Furthermore, because the analysis was heavily reliant on a process of interpretation (Braun & Clarke, 2013), it is likely that even a researcher with a similar academic background would have coded the data somewhat differently. As discussed in section 3.2.4.3, this issue of the reliability as well as generalizability of the findings will be addressed in the next chapter where the analysis of the current chapter will be followed-up with a quantitative test of the hypotheses that will be developed from the findings of this study.

Despite some of these limitations of the methods used in this study, the findings show that the chosen methods here were appropriate to answer the research question. That is, participants' views of the antecedents of their energy behaviour have been investigated and were mapped onto the CADM. Moreover, although some CADM factors may influence behaviour in a more unconscious fashion, participants' discussions showed that people are able to reflect on unconscious processes using this methodology as they frequently discussed their energy habits.

3.4.4 Future directions

The findings of this study suggest that the CADM is relevant for energy behaviour, but this needs to be confirmed using quantitative methods. A quantitative study can test the applicability of the model to energy behaviour, and test the relative influence of the different factors on energy behaviour. Furthermore, a quantitative follow-up study can test whether the applicability of the CADM can be enhanced by including the two variables that were observed to be relevant in the participants' perspectives on their energy behaviour: value-orientation and environmental identity. By using a quantitative approach, the influences of the social context on the data can be diminished and a confirmatory approach can be avoided. A more representative sample of the population could be included so that the statistical analysis will allow for the generalisation beyond the sample. A quantitative follow-up study will also reduce the influences of the researcher's background on the analysis and interpretation of the data. Therefore the next chapter will report on a quantitative study that tested the application of the CADM to energy use.

3.4.5 Conclusion

This study has provided an account of the participants' perspectives of their energy consumption and mapped this onto the CADM model. The findings show the relevance of the CADM to energy behaviour, but additional factors were also suggested. Participants especially seem to identify external factors that motivate their energy behaviour which contrasted their positive attitudes towards energy conservation.

Chapter 4: Modelling Energy Behaviour: An Application of the Comprehensive Action Determination Model

Models used to explain environmental behaviour tend to focus on normative and intentional processes. The Comprehensive Action Determination Model (CADM) is the first to integrate these processes with habitual and situational factors that are likely to be relevant to energy behaviour. Therefore, the study discussed in the current chapter tested the applicability of the model to energy behaviour. Moreover, three variables that were found to be relevant to energy behaviour in Chapter 3, are not part of the CADM and therefore an extended version of the CADM was proposed and tested. An online study (N=247) was conducted in which each variable of the CADM and additional variables were measured. Models were tested using Structural Equation Modelling and the CADM was found to account for 57% of variation in energy use whereas classical models such as the Theory of Behaviour and Norm Activation Model could only account for 32% and 35% of variance in energy behaviour. These results therefore show the value of the CADM in explaining environmental behaviours, particularly behaviour that is habitual and context dependent. Although the inclusion of the additional variables did not improve the model fit or the explained variance in energy behaviour, biospheric values and environmental identity did improve links within the model and should therefore be considered to be incorporated in relevant models.

4.1 Introduction

The literature review in Chapter 2 showed that the Theory of Planned Behaviour (TPB; Ajzen, 1991) could only account for 2-5% of variance in household energy use (Abrahamse & Steg, 2011; Abrahamse & Steg, 2009) and 7% in energy savings (Abrahamse & Steg, 2009). Furthermore this model has often been criticised for the intention-behaviour gap, meaning that behaviour often does not follow from intentions (Armitage & Conner, 2001; Bamberg & Schmidt, 2003; Randall & Wolff, 1994; Sheeran & Orbell, 1998). The Norm Activation Model (NAM; Schwartz, 1977) has been found to explain energy saving behaviour over and above the TPB (but not energy behaviour), yet a combination of these two models could still only account for 11% of variance in energy saving behaviour (Abrahamse & Steg, 2009). The Comprehensive Action Determination Model (CADM; Klöckner & Blöbaum, 2010) combines the TPB and the NAM with habits and objective constrains in an attempt to increase the amount of explained variance in behaviour. By integrating contextual factors with psychological factors the CADM seeks to go beyond the previously discussed psychological models like the TPB and NAM and provide a more rounded, and perhaps more successful, explanation of behaviour. It thereby implicitly sees behaviour as the product of the person's conscious choices, their unconscious influences and also their environment.

As discussed in Chapter 2, various versions of the model have been applied to travel-mode choice (Klöckner & Blobaum, 2010; Klöckner & Oppedal, 2011), recycling behaviour (Klöckner & Oppedal, 2011) and adaptation of new heating systems (Sopha & Klöckner, 2011), as well as a range of environmental behaviours (Klöckner, 2013). In these replications, the amount of variance that could be accounted for in the target behaviour ranged from as low as 36% when various environmental behaviours were combined, to 65% of the variance in travel-mode choice behaviour. No previous study has tested the model in relation to energy use, yet in Chapter 2 the literature on most of the CADM factors were found to be relevant to energy consumption. Furthermore, the study reported in Chapter 3 indicated that the CADM is relevant to energy behaviour and the discussions of the participants suggested that this model may be successful in accounting for a large amount of variance in energy use. The current study aimed to build on the previous study by testing whether the CADM can be successfully applied to energy saving behaviour in a quantitative study. Furthermore, similar to Klöckner and Blöbaum (2010), a *theory-driven* modelling approach was employed, meaning that various models were compared to gain an insight in the explanatory power of a specific theory (van den Broek, 2012). That is, the TPB, NAM and a combination of the two models were tested and compared with the CADM to assess if the CADM has incremental predictive power compared to traditional models. Therefore, this study replicated the study by Klöckner and Blöbaum (2010) that introduced the CADM. Although the methods and operationalisation of the concepts in this study was similar to the study by Klöckner and Blöbaum (2010), this study did not apply the model to travel-mode choice, but instead the model was applied to energy saving behaviour.

Furthermore, in the study in Chapter 3, alternative variables arose that may be useful in predicting energy use. That is, the CADM's explanatory power may be enhanced by including environmental identity, biospheric values and descriptive norms. This study has therefore tested if an extended version of the CADM, including environmental identity, biospheric values and descriptive norms, increased the predictive power of the model.

These variables were not included in the original version of the CADM even though the CADM explicitly aims to predict environmental behaviour and the relevance of these factors to environmental behaviour has been well established in previous research. Perhaps the omission of these factors can be attributed to the confirmatory approach that has been used, in which established models have been integrated to form the CADM whereas an exploratory approach would include variables depending on their predictive power. Furthermore, alternative variables may not have been included to keep the model as parsimonious as possible.

However, in various applications of the CADM, value measures have been added to the CADM. That is, the New Environmental Paradigm (NEP; Dunlap et al., 2000) predicted personal norms instead of the awareness of consequences and awareness of need variables in an application of the CADM to the uptake of wood pellet heating (Sopha & Klöckner, 2011). In this study only the subscale 'balance of nature' could predict personal norms which reflects perceptions of the extent to which nature can cope with the impact of humans. Moreover, the NEP, self-enhancement and self-transcendent values (Schwartz & Bilsky, 1990) were included in the meta-analytic structural equation model that predicted various sustainable behaviours (Klöckner, 2013). Results showed that self-transcendent values and NEP were significantly (although not strongly) correlated with personal norms, but not self-enhancement values (Klöckner, 2013). The self-enhancement dimension corresponds to egoistic values whereas the self-transcendence dimension corresponds to biospheric values (Schultz, 2005). These results therefore further suggest that the CADM may benefit from the inclusion of biospheric values, or the concern for the quality of nature for the environment's sake (Steg, Berg, & Groot, 2012).

Furthermore, the study reported in Chapter 3 also highlighted the relevance of environmental identity to energy behaviour. Environmental identity reflects the extent to which a person views themselves as a person who acts environmentally-friendly (van der Werff et al., 2013) and has been found to influence energy saving intentions and energy saving behaviour (Gatersleben, Murtagh, & Abrahamse, 2012; van der Werff et al., 2013). Furthermore, environmental identity has been suggested to influence personal norms (van der Werff et al., 2013) and indeed has been found to affect personal norms regarding electric car purchase (Barbarossa, Beckmann, De Pelsmacker, Moons, & Gwozdz, 2015). Therefore, environmental identity was included in the extended version of the CADM as an antecedent of personal norms, intentions and behaviour. Although biospheric values differ from environmental identity as values do not involve a self-reflection but rather constitute guiding principles in one's life, biospheric values have been found to be positively related to environmental identity (Gatersleben, Murtagh, & Abrahamse, 2012) and personal norms (Nordlund & Garvill, 2003). Therefore biospheric values were included as a predictor of personal norms and environmental identity.

One component of the CADM is social norms, yet, and inspection of the items that were used to measure this construct by Klöckner (2013) showed that only perceptions of injunctive norms were assessed. Cialdini, Reno and Kallgren, (1990) first introduced the distinction between descriptive norms, which comprise of common behaviour, and injunctive norms; reflecting beliefs of what constitutes morally (dis)approved behaviour. Descriptive norms have often been found to affect environmental behaviour (e.g. Cialdini et al., 1990; Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007; Schultz, Khazian, & Zaleski, 2008). It is likely that the effect of descriptive norms on behaviour is mediated by personal norms, just as injunctive norms in the CADM. That is, the perception of the extent to which others adhere to a norm can influence feelings of responsibility to engage in environmental behaviour and thereby the willingness to engage in the specific behaviour. Therefore, the CADM was extended by included descriptive norms in addition to the injunctive norms that are currently included in the model to test if the addition of these factors to the model increased the model's ability to account for variation in energy behaviour.

4.1.1 Research aims

The current study aimed to replicate the study by Klöckner and Blöbaum (2010) by testing the application of the series of models addressed in their study to energy behaviour. Specifically, following Klöckner and Blöbaum, structural equation modelling will be employed to compare the model fit of the TPB, NAM, a combination of the TPB and NAM and CADM. It was expected that the CADM would result in the best model fit for energy behaviour, similar to the findings in the original publication. Furthermore, this study aimed to test an extended version of the CADM that included variables that were found to be relevant to energy behaviour in previous literature, as well as in the study reported in Chapter 3. This extended model was expected to have an improved model fit over the CADM due to the inclusion of the additional factors.

4.2 Method

An online survey was conducted which included measurements for all the CADM and additional factors and this data was analysed using Structural Equation modelling.

4.2.1 Ethical approval

Approval was granted by the University of Bath Department of Psychology ethics committee, reference number 13-004.

4.2.2 Participants

The sample consisted of 247 participants (M_{age}= 27.33, SD_{age}= 10.69, 69.6% female) who varied in nationalities (67 % British, 7% Dutch, 4% Germany and other nationalities) and living arrangements (31% living with friends, 20.2% living on university campus, 19.4% living with a partner). Participants were recruited through online and offline advertising which offered a chance of winning a gift voucher in exchange for their participation or, alternatively, participants could earn course credits with their participation when applicable. No restrictions were imposed on the eligibility of participants except for standard ethical age requirements (min.

of 18 years). Responses for many variables were missing for eight participants and therefore these participants were excluded from the analysis.

4.2.3 Measures

An online questionnaire was designed that included items to measure the CADM constructs, environmental identity, descriptive norms and biospheric values (see Appendix B). The first part of this questionnaire also contained items for the study reported in Chapter 7, but this chapter will only focus on the items relevant for this study. The eight CADM variables were measured using Klöckner & Blöbaum (2010)'s 28 items, which included two to six questions to measure each construct. These questions were adapted to apply to energy behaviour where necessary (e.g. "*Driving a car contributes to climate changes*" became "*Energy use contributes to climate change*") and these items were rated on a 7 point Likert scale (1=*Strongly disagree,* 7=*Strongly agree*).

Although attitudes are included in the CADM proposed in the original publication (Klöckner & Blöbaum, 2010), the authors have not included this factor in their test of the model in the same publication, for reasons that are unclear. Because this study aimed to replicate the test of the CADM by Klöckner and Blöbaum, attitudes towards energy conservation behaviour were also omitted in the current study which allowed for a direct comparison of model fit between the models in the original publication and the models in the current study. Habits were only measured using the Self-Report Habit Index (Verplanken & Orbell, 2003) using the same Likert scale and not with the Response Frequency Measure that was used by Klöckner and Blöbaum, as this measure did not lend itself for adaptation to energy consumption. To measure objective control of energy use, participants were asked whether they could control their thermostat, lights, radiator and washing machine in their house, giving them three possible answer possibilities (*yes/no/I don't know*). The latter response was coded as missing data, the '*yes*' responses were recoded as 1 and '*no*' as 0 to create a binary variable. Similar dichotomous variables have been coded the same way in application of SEM in AMOS software (the software used in this study) and therefore the use of this binary variable is appropriate (Arbuckle, 2012). Although continuous items are preferred in SEM (Norman & Streiner, 2003), the estimation method that will be used in the analysis (see section 4.2.5.4) can be applied to dichotomous variables (Skrondal & Rabe-hesketh, 2005).

Behaviour was measured using a self-report measure on daily household energy use that covered a range of household domains (e.g. "*Only boiling the amount of water I need in the kettle*", "*Air-dry clothes instead of using a tumble dryer*", "*Switching off the light when I leave the room*"). Participants indicated how often they had engaged in 10 different energy behaviours over the past week on a 7 point Likert scale (1=*Never*, 7=*Every time*).

The additional variables that are not part of the CADM were measured using the value-orientation scale by Steg and colleagues (Steg et al., 2012) to measure biospheric values and the items developed by Whitmarsh & O'Neill (2010) to measure environmental identity. Furthermore, descriptive norms on energy saving behaviour were measured with items that assessed the perception of energy use of other people in the participant's country, family and the behaviour of their friends (e.g. "*I think my family member try to limit their energy use*"). Two items of environmental identity and two items of perceived behavioural control were reverse scored to ensure that higher scores on all items indicated the same tendency in relation to the respective construct.

It is likely that the items for certain constructs will not have high internal reliability as variation can be expected across certain items (e.g. the amount of control participants perceive in relation to different appliances). However, observable indicators do not need to be tested for internal consistency prior to structural equation modelling as it incorporates confirmatory factor analysis (Bollen, 1989). Therefore, no reliability analysis will be reported on the variables included in the models.

4.2.4 Introducing structural equation modelling

For this analysis, Structural Equation Modelling (SEM) was performed using AMOS software (Arbuckle, 2013). The following sections will briefly introduce the methods, assumptions and other relevant properties of SEM, and Appendix BC provides supplementary material on the method of SEM. SEM is a complex method with little consensus on method and terminology in the field. This introduction will therefore by no means be exhaustive and merely provide a background for the interpretation of the results. Readers who would like to learn more on SEM are recommended the work by Kline (2005) and Ullman (2013) for a more theoretical description of SEM and the work by Schumacker and Lomax (2010) and Byrne (2010) for applications of SEM. A step-by-step application of SEM to the current dataset will follow. These sections will assume the reader has a working knowledge of confirmatory factor analysis and regression analysis.

SEM is an umbrella term for several statistical models that test the validity of substantive theories with empirical data (Lei & Wu, 2007). SEM is sometimes also referred to as path analysis, causal modelling, causal analysis, simulations equation modelling, confirmatory factor analysis, and covariance structure analysis (Lei & Wu, 2007; Ullman, 2013). The aim of SEM is to test how consistent the data is with a theory that has been specified a priori, thereby taking a confirmatory approach (Lei & Wu, 2007). SEM integrates two parts: a *measurement model,* that is tested using Confirmatory Factor Analysis (CFA), and a *structural model* that is tested using multiple regression (see Appendix B). Where the measurement model assesses the relation between the observed variables and their underlying latent constructs, the structural model examines the relations between these latent constructs (Hoyle, 2000).

One of the benefits of SEM is that it considers the relationships among latent variables that are inferred form observable variables and are therefore not directly measured (Lei & Wu, 2007). A latent variable could be defined as whatever its multiple indicators have in common with each other. That is, a latent variable, or construct, is an unobservable variable for which no measurement instrument exists (Blunch, 2013). Furthermore, SEM is the only method that facilitates complete and simultaneous tests of complex relationships (Ullman, 2013). That is, SEM produces a measure of model fit as well as regression coefficients between variables and therefore provides a more detailed evaluation of a model compared to alternative approaches such as (a combination of) confirmatory factor analysis, mediation or regression analysis. This type of analyses can be applied to non-experimental cross-sectional data (as well as longitudinal and experimental data), as is the case for this study (Lei & Wu, 2007).

This method therefore assesses many aspects of the model including how observable variables relate to latent variables, the comparison of the fit of several models, the amount of variance that can be explained in a endogenous (or dependent) variable in the model and it allows for comparison of relationships within the model using parameter estimates (Ullman, 2013).

4.2.5 Conducting SEM

SEM consists of the following processes: model specification, data collection, model estimation, model evaluation and in some cases model modification. The following sections will specify the details and issues of each of these phases (Lei & Wu, 2007), and will be applied to the current study.

4.2.5.1 Model specification

SEM starts with outlining the model against which the data will be tested for consistency. The most common method used for model specification is the Bentler-Weeks method (Bentler & Weeks, 1980). With this method, each variable in the model is classified as either an exogenous (which is not caused by variables included in the model) or endogenous variable (which is caused by at least one variable included in the model) and the links between factors are hypothesised (Bentler & Weeks, 1980). The parameters that will be estimated through the analyses are the regression coefficients and the variances and covariance of the independent variables (Bentler & Weeks, 1980). If multiple observed variables are loading onto a latent variable, one parameter needs to be constrained to 1 to serve as a reference point for the other parameters and serve as the scale for the latent variable (Ullman, 2013). This means that the parameter of this path will not be estimated from the data, however, the standardised regression estimate can be produced (Lei & Wu, 2007).

This study had two aims. First, this study tested the components of the CADM in relation to energy use, and assessed how well the model could account for energy behaviour. Therefore, this model was built and tested stepwise using four models similar to the original introduction of the CADM (Klöckner & Blöbaum, 2010). These four models were the TPB, the NAM, a combination of the TPB and NAM (as the CADM is a combination of these models) and the full CADM. The second aim of this study was to examine if the model could benefit from adding the new ideas generated in the study reported in Chapter 3. Therefore, after testing the CADM model, an extension of the CADM was tested that included the factors that emerged in the previous study (see Figure 6). The position of these factors in the model and the links between these factors and the CADM factors is based on previous literature (see section 4.1). This model included descriptive norms in addition to injunctive norms that predicted personal norms. Furthermore, this extended model included environmental identity that predicted personal norms, intention and behaviour. Environmental identity was preceded by biospheric values and also predicted personal norms.

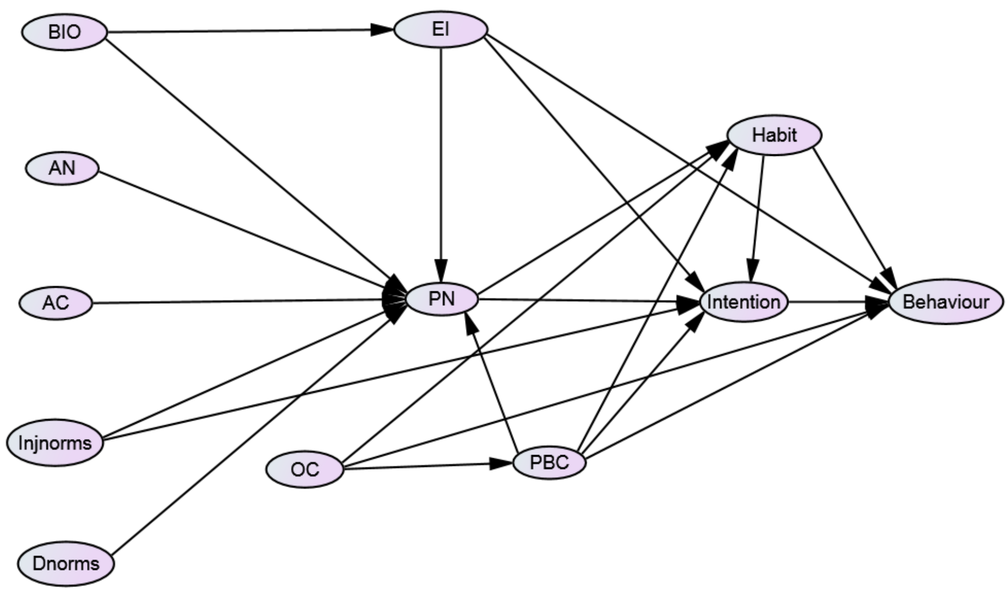

Figure 6: Extended version of the CADM
BIO= Biospheric values, AN= Awareness of Need, AC= Awareness of Consequences, Injnorms= Injunctive Norms, Dnorms= Descriptive norms, EI= Environmental Identity, PBC= Perceived Behavioural Control, PN= Personal Norms, OC= Objective Control, H= Habits

4.2.5.2 Model identification

An important issue in SEM is model identification. Model identification refers to the number of variances and covariances relative to the number of parameters that need to be estimated in the model (e.g. regression coefficients, variances and covariances) (Lei & Wu, 2007). That is, it reflects to what extend there is sufficient variance in the data to be able to produce estimations for each parameter. A model is said to be over-identified when there are more variances and covariances that are produced by the data than parameters that need to be estimated, which means that there is a unique numerical solution for each of the parameters in the model, and the model can be run (Ullman, 2013). When the number of unknown parameters equals the number of variances and covariances, the model is said to be just identified, in which case the model has no degrees of freedom and the model fit cannot be assessed (Ullman, 2013). When a model has more parameters that need to be estimated than known variances and covariances, the model is under-identified which means that not all parameters can be estimated and the model needs to be re-specified (Lei & Wu, 2007). SEM software (including AMOS software) will report when a model is not identified which will imply that the results of the SEM analysis cannot be interpreted (Blunch, 2013).

4.2.5.3 Data collection

The complexity of the model, meaning the number of parameters that will need to be estimated, needs to be taken into account during data collection to ensure that the sample size will allow an over-identified model. Most researchers recommend a sample size of at least 200 (Lei & Wu, 2007). The sample in this study consisted of 247 participants and therefore this condition was satisfied.

4.2.5.4 Model estimation

A common method that is used to estimate the discrepancy between the observed covariance matrix and the model-implied covariance matrix is the Maximum Likelihood Estimation (MLE) method (Lei & Wu, 2007). MLE is used to minimise the difference between the observed and estimated population covariances. Alternative estimation methods include Unweighted Least Square Estimation (ULSE) and Weight Least Square Estimation (WLSE) but these methods have been found to be inferior to MLE as the latter method is scale-free and scale invariant (Kline, 2005; Norman & Streiner, 2003). When using ULSE, on the contrary, the parameter estimates depend on the scale of the measurement, meaning that different results would be obtained if a construct would have been measured on a 5-point scale instead of a 7-point scale (Norman & Streiner, 2003). This method therefore requires all the observed variables to be measured on the same scale (Kline, 2005) and this requirement was not met in this study. Furthermore, standard errors tend to be larger using ULSE which implies reduced power when testing the parameter estimates (Kline, 2005). For a continued discussion of the limitations of ULSE see section 4.3.1.1. The WLSE does not bare these limitations, however, a meta-analysis comparing MLE and WLSE demonstrated that WLSE for the analysis of ordinal data (as measured in this study) tends to result in high levels of bias for the parameter estimates, especially with smaller samples sizes (as is the case in this study) (Hoogland, & Boomsma, 1998).

Applying MLE in SEM does require a few assumptions to be met. Although in the literature on SEM, there seems to be quite a varied perspective on which assumptions or conditions needs to be met to apply SEM using MLE, the most important (and widely supported) assumptions include absence of missing data, absence of multicollinearity among variables and multivariate normality of the dependent variables (Bollen, 1989; Kline, 2005; Schumacker & Lomax, 2010; Ullman, 2013). Multivariate normality means that all variables and all the linear combinations of variables are normally distributed (Ullman, 2013). These assumptions among other issues, will be addressed in the data cleaning section below (section 4.2.6).

4.2.5.5 Model evaluation

A wealth of model fit indices have been developed to evaluate the model fit with SEM. These indices tend to have different fit criteria and cover diverse aspects of the model fit and thereby belong to different categories of model fit indices. One index will be reported from each model fit category, based on recommendations in the literature (see Appendix D for a detailed justification of the selection of model fit indices). The selected model fit indices are displayed in Table 1.

Table 1: Selected model fit indices, their respective index categories and fit criteria

Model fit index	Type of index	Fit criteria
Standardised Root Mean Square Residual (SRMSR)	Absolute fit measure	<.10 (Kline, 2005)
Comparative Fit Index (CFI)	Relative fit	>.90 (Kline, 2005)
Akaike Information Criteria	Model Parsimony Indicator	Model with smallest value has best fit (Norman & Streiner, 2003)
Root Mean Square Error of Approximation (RMSEA)	Non-central Chi-square distribution	<.06 (Hu & Bentler, 1999)

Besides the overall-model fit, individual parameter estimates can be interpreted to evaluate the relationship between individual variables in the model. The coefficients for the structural paths and their statistical significance can be interpreted in a similar way as regression coefficients. The standardised beta coefficients will be reported alongside the unstandardized estimations to facilitate direct comparison of the paths within and across models.

4.2.5.6 Model modification

A potential final stage of SEM is model modification in which the model is re-specified in case of poor model fit. A large model modification index may indicate that the model fit can be significantly improved if a fixed parameter is freed. However, if the changes in the model are not supported by theory, it is difficult to justify model re-specification. Indeed, many researchers suggest that this conflicts with SEM's confirmatory approach and this exploratory approach can lead to chance capitalisation (Lei & Wu, 2007). Furthermore, the authors of the original publication testing the CADM (Klöckner & Blöbaum, 2010) have not applied any post-hoc modifications to improve model fit and to be able to compare the results, no modifications will be made to the models in this study.

4.2.6 Data cleaning

The following issues will be addressed in this section: outliers, missing data, multivariate normality, and multicollinearity to meet SEM's assumptions and, where appropriate, the corresponding data cleaning measures are discussed.

A common method in SEM is to use Mahalanobis distance to assess multivariate outliers, which are observations that score an unusual combination on two or more variables (Ullman, 2013). However, this study used 7-point Likert scales which did not leave much room for extreme scores. Therefore, scores at both ends of the scale are unlikely to reflect an unreliable or invalid response and were more likely to reflect genuine responses. Indeed, when outliers are a legitimate part of the data, they should not be removed (Tabachnick & Fidell, 2013). Therefore, to ensure that no meaningful data was omitted, no outliers were removed from this dataset.

Another potential issue in SEM is multicollinearity, meaning the correlation between independent variables. SEM software, including AMOS software, checks for multicollinearity when running SEM and will abort the analysis when appropriate therefore there is no need to check for multicollinearity prior to the analysis (Schumacker & Lomax, 2010; Ullman, 2013).

A key assumption of MLE is that there are no missing values in the dataset (Kline, 2005; Schumacker & Lomax, 2010; Ullman, 2013). Only a small proportion of the total dataset was missing (1.4%), although the proportion of missing values was slightly higher for the objective control variables (2.00-5.30%), as *'I don't know'* responses were coded as missing. The data was found to be missing completely at random using Little's MCAR Test (χ^2 (3245, N=247)=3348.53, p>.05). Therefore the data could be imputed using mean-substitution imputation, the most commonly used method to deal with missing data in social psychology (Judd & Kenny, 2010). For the objective control variables, the new values were rounded up or down to the closest binary value, after the data was imputed. This method has been found to be superior in dealing with missing data compared to more conventional methods such as list-wise or pairwise deletion that can result in biased estimates of parameters or their standard error and make inefficient use of the data (Allison, 2003).

Another assumption that is often stressed in SEM introductory textbooks is multivariate normally distributed endogenous variables (Ullman, 2013). Because multivariate normality assumes that all variables and all the linear combinations of variables are normally distributed, infinite number of linear combinations are possible, meaning it can be very difficult to test for multivariate normality and existing tests have been found to be too sensitive (Ullman, 2013). However, multivariate non-normality can be detected by inspecting the skewness of univariate distributions (Kline, 2005). The 48 observed variables differed in the amount and direction of the skew and added to a squared total skew of 80.50 (see Appendix E). Skew was removed from items by transforming variable with positive skew with a natural logarithm. Variables with negative skew were reversed scored (X_{new}= ($Xmax$+1)-X) and a natural logarithm was applied, after which the variable was reversed back to maintain the same interpretation. All variables that benefited from transformation had a maximum score of 7 (Ln(7)=1.95), and therefore this resulted in the following transformation formula: X_{new}=1.95-(LN(8-X)). Variables which skew could not be improved with a transformation were left untransformed. After these transformations the squared total skew was reduced to 50.02, most of which can be attributed to the high levels of skew in the objective control items, which were not transformed. That is, skew in these items was to be expected due to the binary nature of the values of these variables, and a transformation would not result in normal distributed data for this variable.

4.3 Results

The following sections will report the results of the analysis for each model, starting with the TPB, the NAM, followed by a combination of the TPB and NAM, then the CADM, and finally the extended CADM. The diagrams for each model will only include the standardised regression weights to allow for direct comparison across parameters (see Appendix B for a description of the symbols used in these diagrams). Furthermore, unstandardized parameters will be reported in tables as these can be tested for significance (unlike the standardised coefficients as significance tests are not provided for these in AMOS software). The parameter estimates for the covariances and correlations are also reported in these tables in the regression coefficients columns.

4.3.1 Testing the Theory of Planned Behaviour

To be able to directly compare the current study with Klöckner and Blöbaum (2010)'s paper, attitudes were also omitted from this model. The model was constructed similarly to Klöckner and Blöbaum (2010), in which social norms (rephrased as injunctive norms in the current study) influences intention, which in turn affects behaviour as well as perceived behavioural control.

4.3.1.1 Issues with negative error variance

When this model was run, a negative error variance was reported for the error associated with the first indicator of intention (error = -.057), meaning that the interpretation of the results was compromised. In SEM literature, negative error variance implies an improper solution as variance estimates cannot logically take any negative values (Lei & Wu, 2007). These negative variance estimates are common occurrences in SEM, known as Heywood cases, and these cases can be produced by various issues in the dataset (Kolenikov & Bollen, 2012). The causes of Heywood cases include outliers (Bollen 1987), multicollinearity (Lei & Wu, 2007), empirical underidentification (Rindskopf 1984), missing data (Wothke 1993), sampling fluctuations (van Driel 1978; Boomsma 1983; Anderson and Gerbing 1984) or structural misspecification (van Driel 1978; Dillon, Kumar, and Mulani 1987; Sato 1987; Bollen 1989), yet most often, they are caused by an insufficient number of observable variables that are to define the latent variable (McDonald, 2014). The latter explanation for the negative variance is the most likely explanation for the Heywood case detected in this analysis as the latent variable intention was only estimated by two observable variables whereas a minimum of three observable variables is recommend (McDonald, 2014).

A range of approaches have been proposed to manage negative error variance. First, Heywood cases have been found to be less common when using an alternative estimation method such as Unweighted Least Square Estimation (ULSE) and these alternative methods are therefore recommended when Maximum Likelihood Estimations (MLE) result in Heywood cases (McDonald, 2014). However, this approach has many disadvantages among which is that the results of the ULSE depend on the scale of the measurement (Norman & Streiner, 2003). Furthermore, the number of available model fit indices with this estimation method is limited compared to when using MLE (Blunch, 2013). Moreover, when ULSE is used, no standard errors or test statistics can be produced meaning that path coefficients cannot be tested to be different from 0 (Bollen, 1989).

An alternative approach involves restraining the error variance to a fixed value, either to a small positive value or to 0 (Gerbing & Anderson, 1987). These latter solution would allow the use of MLE instead of ULSE which is preferable considering the disadvantages of the use of ULSE, and the advantages of MLE discussed in section 4.2.5.4. Nevertheless, to be able to constrain the error of the observed variable, the negative variance cannot be significantly different from 0 so that the negative variance can reasonably be attributed to sampling error (Dillon, Kumar, & Mulani, 1987; Gerbing & Anderson, 1987). The variance estimate (error =

-.057) was not found to be significantly different from zero (critical ratio = -.165, *p* =.869). This means that that the confidence interval around the negative error variance includes 0 and positive values, hence sampling error is likely to have caused the negative variance estimate and restraining error variance is justified (Gerbing & Anderson, 1987).

Setting error variance to 0 has been found to have been very effective in yielding a proper solution without resulting in Heywood cases, extreme standard errors, or identification problems and a meaningful interpretation of the estimates is not compromised (Dillon et al., 1987; Gerbing & Anderson, 1987). Furthermore, it is arguably a more conservative approach compared to setting the error variance to a small positive value as it is closer to the original estimate which could not be proven to be significantly different from 0. Therefore, the error variance of the observable variable '*Intention1*,' was set to 0 to resolve the improper solution resulting from the Heywood case in this model.

4.3.1.2 SEM analysis results for the TPB

The results of the analysis, with this additional constraint, showed a reasonably good fit according to the model fit indices (SRMR: .068, CFI: .876, AIC: 310.207 and RMSEA: .055). Therefore, the parameter estimates can be interpreted (see Table 2 and Figure 7). These parameter estimates demonstrate that all observed variables loaded sufficiently on their respective latent variables. However, the standardised regression estimate between the latent intention variable and the observable variable *'intention1'* was very high (β= 1.00), which is likely a reflection of the negative error variance issues described above.

Next, inspecting the regression coefficients between latent variables, two paths were found to have very low parameter estimates (see Table 2). That is, intention could not be significantly predicted by perceived behavioural control (*B*=0.03, p >.05). Furthermore, the results suggest a slight intention-behaviour gap as the unstandardized parameter estimate between these variables was bordering on significant (*B*=0.55, p = .05). However, perceived injunctive norms did predict intention to save energy (*B*=0.75, p<.001), and perceived behavioural control did influence behaviour (*B*=0.99, p<.001). The results further show that the model could explain 32% of the variance in energy saving behaviour, but only 17% of variance in intention to save energy. Finally, injunctive norms and perceived behavioural control were moderately correlated with each other (*r*=.32).

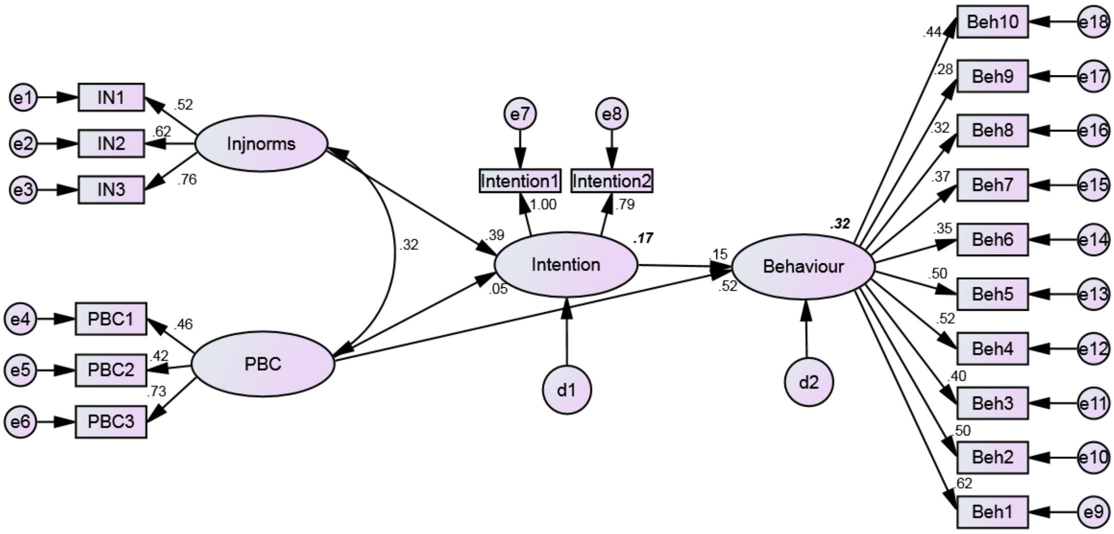

Figure 7: SEM results for the TPB with standardised regression coefficients shown

Table 2: Detailed results from SEM analysis of the TPB

Measurement model					**Structural model**					
Model Link	***B***	**S.E.**	***p***	**Beta**	**Model Link**	***B***	**S.E.**	***p***	**Beta**	**R^2**
IN→ IN1	1.00	-	-	.52	IN→INT	0.75	.18	**<.001**	.39	
IN→ IN2	1.01	.17	**<.001**	.62	PBC→INT	0.55	.85	.52	.05	
IN→ IN3	1.42	.24	**<.001**	.76	INT					.17
PBC→PBC1	1.00	-	-	.46						
PBC→PBC2	1.33	.32	**<.001**	.42	INT→BEH	0.03	.01	.05	.15	
PBC→PBC3	1.54	.34	**<.001**	.73	PBC→BEH	0.99	.25	**<.001**	.52	
INT→INT1	1.00	-	-	1.00	BEH					.32
INT→INT2	0.81	.04	**<.001**	.79						
BEH→BEH1	1.00	-	-	.62	IN↔PBC	.05	.02	**<.01**	.32	
BEH→BEH2	1.05	.18	**<.001**	.50						
BEH→BEH3	0.97	.20	**<.001**	.40						
BEH→BEH4	1.02	.17	**<.001**	.52						
BEH→BEH5	1.01	.17	**<.001**	.50						
BEH→BEH6	0.83	.19	**<.001**	.35						
BEH→BEH7	0.66	.14	**<.001**	.37						
BEH→BEH8	0.74	.18	**<.001**	.32						
BEH→BEH9	0.61	.17	**<.001**	.28						
BEH→BEH10	1.10	.21	**<.001**	.44						

IN= Injunctive Norms, PBC= Perceived Behavioural Control, INT= Intention, BEH= Behaviour

4.3.2 Testing the Norm Activation Model

The NAM predicts behaviour from personal norms which in turn are preceded by awareness of need, awareness of consequences, injunctive norms and perceived behavioural control. The model fit indices for the NAM indicated a good model fit (SRMR: .074; CFI: .90; AIC: 546.80; RMSEA: .05). Compared to the model fit results of the TPB, the SRMR and AIC indicated slightly poorer fit for the NAM whilst the CFI and RMSEA showed slight improved fit for this model suggesting that there may not be a great difference in overall model fit between the two models.

The CFA again showed sufficient factor loadings for all observed variables on their respective latent variables (see Table 3 and Figure 8). The parameter estimates for the paths between latent variables showed that only the path between personal norms and injunctive norms resulted in a parameter that was found to be significantly different from 0 (B=0.69, p<.001), meaning that awareness of need, awareness of consequences and perceived behavioural control could not significantly predict personal norms. However, these factors together did explain 59% of the variance in personal norms. In turn, personal norms could significantly predict behaviour (*B*=0.78, *p*<.001) as well as perceived behavioural control (*B*=0.08 *p*<.001). Together these variables explained 35% of the variance in behaviour. Furthermore, strong correlations were found between awareness of need and awareness of consequences (*r*=.83) whereas perceived behavioural control was not found to correlate strongly with awareness of need (*r*=.08) and awareness of consequences (*r*=.12).

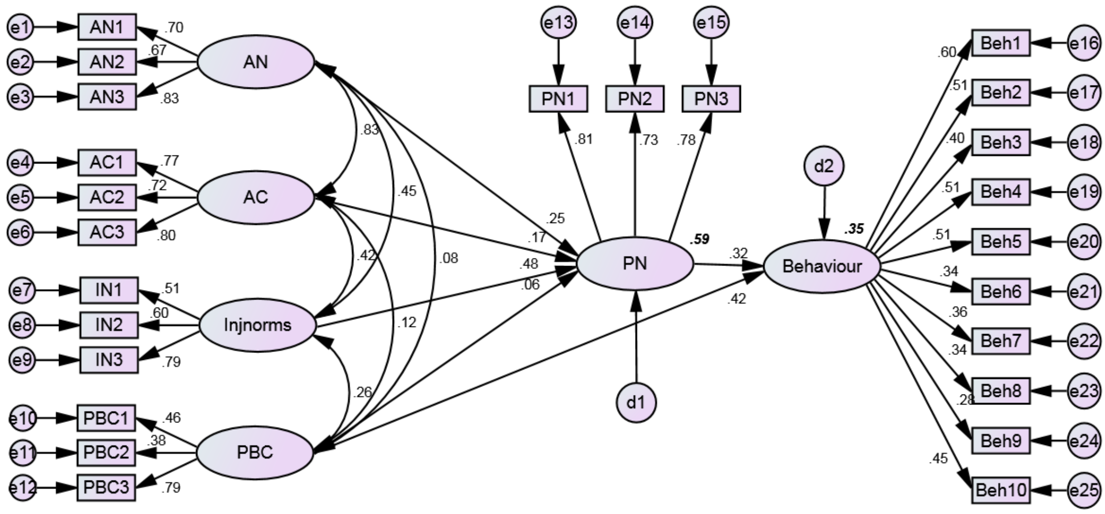

Figure 8: SEM results for the NAM with standardised regression coefficients shown

Table 3: Detailed results from SEM analysis of the NAM

Measurement model					**Structural model**					
Model Link	***B***	**S.E.**	***p***	**Beta**	**Model Link**	***B***	**S.E.**	***p***	**Beta**	**R^2**
AN→ AN1	1.00	**-**	**-**	.70	AN→PN	0.82	.51	.11	.25	
AN→ AN2	0.91	.10	**<.001**	.67	AC→PN	0.49	.44	.27	.17	
AN→ AN3	1.21	.11	**<.001**	.83	IN→PN	0.69	.15	**<.001**	.48	
AC→AC1	1.00	**-**	**-**	.77	PBC→PN	0.48	.53	.36	.06	
AC→AC2	0.87	.08	**<.001**	.72	PN					.59
AC→AC3	1.06	.09	**<.001**	.80						
IN→IN1	1.00	**-**	**-**	.51	PBC→BEH	0.78	.21	**<.001**	.42	
IN→IN2	1.00	.16	**<.001**	.60	PN→BEH	0.08	.02	**<.001**	.32	
IN →IN3	1.51	.23	**<.001**	.79	BEH					.35
PBC→PBC1	1.00	**-**	**-**	.46						
PBC→PBC2	1.21	.29	**<.001**	.39	AN↔AC	.13	.02	**<.001**	.83	
PBC→PBC3	1.66	.38	**<.001**	.79	AN↔IN	.14	.03	**<.001**	.45	
PN→PN1	1.00	**-**	**-**	.81	AN↔PBC	.01	.01	.36	.08	
PN→PN2	0.91	.08	**<.001**	.73	AC↔IN	.15	.04	**<.001**	.43	
PN→PN3	1.02	.08	**<.001**	.78	AC↔PBC	.01	.01	.17	.12	
BEH→BEH1	1.00	-	-	.60	IN↔PBC	.04	.02	**<.05**	.26	
BEH→BEH2	1.11	.19	**<.001**	.51						
BEH→BEH3	0.99	.20	**<.001**	.40						
BEH→BEH4	1.02	.17	**<.001**	.51						
BEH→BEH5	1.06	.18	**<.001**	.51						
BEH→BEH6	0.85	.19	**<.001**	.35						
BEH→BEH7	0.66	.15	**<.001**	.36						
BEH→BEH8	0.82	.19	**<.001**	.34						
BEH→BEH9	0.63	.18	**<.001**	.28						
BEH→BEH10	1.17	.21	**<.001**	.45						

AN= Awareness of Need, AC= Awareness of Consequences, IN= Injunctive Norms, PBC= Perceived Behavioural Control, PN= Personal Norms, BEH= Behaviour

4.3.3 Testing the combination of the TPB and the NAM

Following Klöckner and Blöbaum (2010) a model was specified that was a combination of the TPB and NAM in which perceived behavioural control predicted intentions as well as behaviour and intentions also predicted behaviour. Personal norms did not predict behaviour but did predict intention and was preceded by the same factors as the previously tested NAM. The model fit indices of the model that combined the TPB and the NAM showed a good fit, very similar to the fit of the two models separately (SRMR: .0745, CFI:.909, AIC: 620.79 and RMSEA: .048), except for an increase in the AIC value that was to be expected as the model was more complex (Schumacker & Lomax, 2010).

The parameter estimates for the CFA again showed that all observed variables sufficiently loaded on their latent variables (see Table 4 and Figure 9). The regression weights for the structural regression showed that, again, only injunctive norms could significantly predict personal norms (*B*=0.69, *p*<.001), although all four variables together explained 59% of variance in personal norms. In turn, personal norms was the only variable that significantly predicted intention to save energy (*B*=0.67, *p*<.001) but together with perceived behavioural control and injunctive norms only 33% of the variance in intention was explained. Behaviour was only predicted by perceived behavioural control (*B*=1.14, *p*<.001*)*, while the parameter estimate for intention was bordering on significance (*B*=0.03, *p*=.06) and together they explained 38% of the variance in behaviour. Similar to the last model, a strong correlation was found between awareness of consequences and awareness of need (*r*=.83).

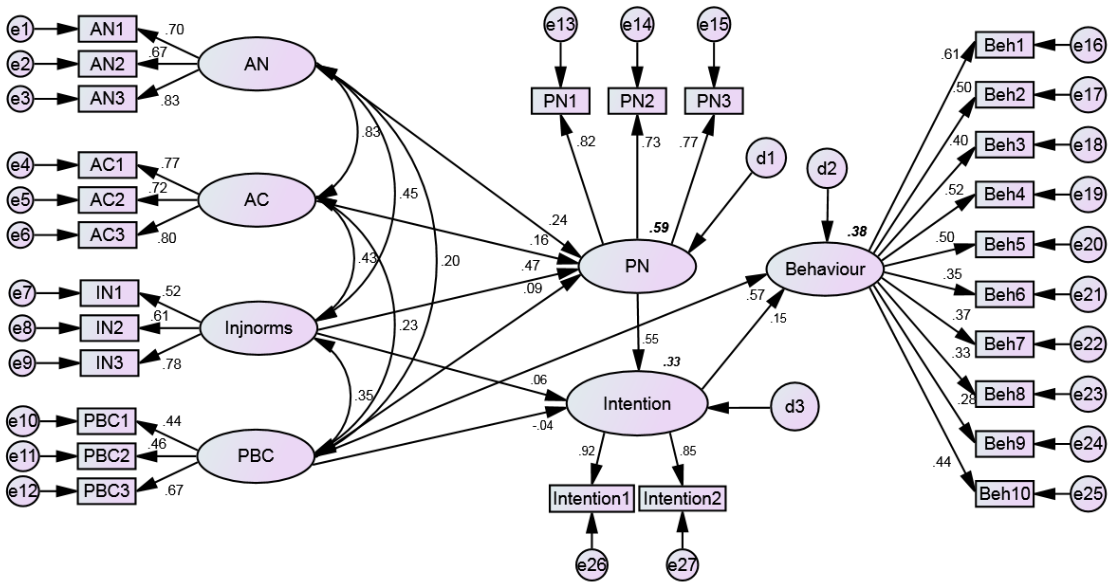

Figure 9: SEM results for the combination of the TPB and the NAM with standardised regression coefficients shown

Table 4: Detailed results from SEM analysis of the combination of the TPB and the NAM

Measurement model					**Structural model**					
Model Link	***B***	**S.E.**	***p***	**Beta**	**Model Link**	***B***	**S.E.**	***p***	**Beta**	**R^2**
AN→ AN1	1.00	-	-	.70	AN→PN	0.81	.51	.12	.24	
AN→ AN2	0.91	.10	**<.001**	.67	AC→PN	0.46	.44	.30	.16	
AN→ AN3	1.21	.11	**<.001**	.83	IN→PN	0.69	.15	**<.001**	.47	
AC→AC1	1.00	-	-	.77	PBC→PN	0.73	.64	.25	.09	
AC→AC2	0.87	.08	**<.001**	.72	PN					.59
AC→AC3	1.06	.09	**<.001**	.80						
IN→IN1	1.00	-	-	.52	IN→INT	0.11	.21	.52	.06	
IN→IN2	1.01	.16	**<.001**	.61	PN→INT	0.67	.14	**<.001**	.55	
IN →IN3	1.48	.22	**<.001**	.78	PBC→INT	-0.41	.85	.63	-.04	
PBC→PBC1	1.00	-	-	.44	IN					.33
PBC→PBC2	1.53	.37	**<.001**	.46						
PBC→PBC3	1.50	.33	**<.001**	.67	PBC→BEH	1.14	.29	**<.001**	.57	
PN→PN1	1.00	-	-	.82	INT→BEH	0.03	.02	.06	.15	
PN→PN2	0.90	.08	**<.001**	.73	BEH					.38
PN→PN3	0.99	.08	**<.001**	.77						
INT→INT1	1.00	-	-	.92	AN↔AC	.13	.02	**<.001**	.83	
INT→INT2	0.96	.08	**<.001**	.85	AN↔IN	.14	.03	**<.001**	.45	
BEH→BEH1	1.00	-	-	.61	AN↔PBC	.01	.01	**<.05**	.20	
BEH→BEH2	1.06	.18	**<.001**	.50	AC↔IN	.15	.04	**<.001**	.43	
BEH→BEH3	0.98	.20	**<.001**	.40	AC↔PBC	.01	.01	**<.05**	.23	
BEH→BEH4	1.02	.17	**<.001**	.52	IN↔PBC	.05	.02	**<.01**	.35	
BEH→BEH5	1.02	.17	**<.001**	.50						
BEH→BEH6	0.83	.19	**<.001**	.35						
BEH→BEH7	0.67	.14	**<.001**	.37						
BEH→BEH8	0.77	.18	**<.001**	.33						
BEH→BEH9	0.61	.17	**<.001**	.28						
BEH→BEH10	1.12	.21	**<.001**	.44						

AN= Awareness of Need, AC= Awareness of Consequences, IN= Injunctive Norms, PBC= Perceived Behavioural Control, PN= Personal Norms, INT= Intention, BEH= Behaviour

4.3.4 Testing the complete Comprehensive Action Determination Model

This model predicted behaviour from habits, intentions, objective and perceived behavioural control. Intentions were preceded by habits, personal norms and injunctive norms, while habits were predicted by personal norms, objective control and perceived behavioural control.

Personal norms were predicted by awareness of consequences, awareness of need, injunctive norms and perceived behavioural control which in turn was preceded by objective control. Results for the CADM model fit indices suggested a very similar fit compared to the previous models except for a sharp increase in the AIC-index, suggesting a strong reduction in parsimony (SRMR: .072, CFI:.899, AIC: 1200.45 and RMSEA:.047).

The CFA showed that all observed variables sufficiently loaded on the latent variables except for the fourth item measuring objective control (controlling lights in accommodation) which loadings bordered on statistical significance (see Table 5 and Figure 10). The results of the structural regressions showed that, again, injunctive norms was the only significant predictor for personal norms (*B*=0.69, p<.001), but together with the other variables, 60% of the variance in personal norms was explained, similar to the 54% of explained variance by Klöckner and Blöbaum (2010). Although objective control significantly predicted perceived behavioural control in the original publication of the CADM (Klöckner & Blöbaum, 2010; *B*=0.83, p<.001), there was no evidence for this in the current study (*B*=-0.05, *p*=.84) and objective control could not account for any variance in perceived behavioural control. Personal norms (*B*=0.17, *p*<.001) and perceived behavioural control (*B*=0.78, *p*<.001) were found to significantly predict habits, and together with objective control (that was not found to predict habits: *B*=0.15, *p*=.72), these factors explained 43% of the variance in habits, which is much less than the 77% in the original test of the CADM. Intentions to save energy could only be predicted by personal norms (*B*=0.79, *p*<.001) and 34% of the variance in intentions could be explained in this model, again much less than the 60% in (Klöckner & Blöbaum, 2010). Finally, habits (*B*=0.39, *p*<.001), objective control (*B*=1.15, *p*<.05) and perceived behavioural control (*B*=0.45, *p*<.01) significantly predicted energy saving behaviour although, as with the previous models, an intention-behaviour gap was present again as there was no significant relation between these two variables (*B*=0.01, *p*=.28), similar to the results in the original paper on the CADM. However, 57% of the variance in behaviour was explained with these four variables, which is slightly lower than the 65% of variance explained by Klöckner & Blöbaum (2010).

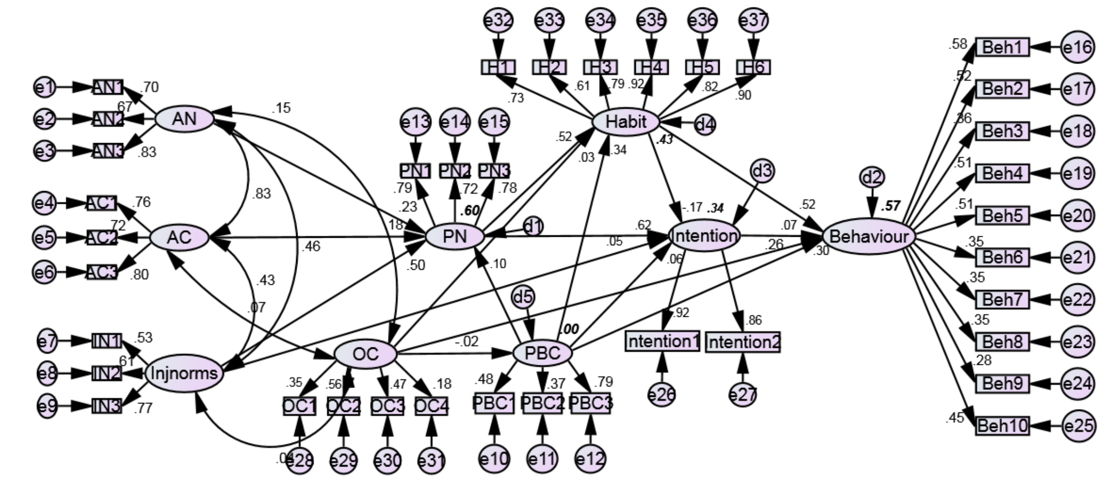

Figure 10: SEM results for the CADM with standardised regression coefficients shown

Table 5: Detailed results from SEM analysis of the CADM

Measurement model					**Structural model**					
Model Link	***B***	**S.E.**	***p***	**Beta**	**Model Link**	***B***	**S.E.**	***p***	**Beta**	**R^2**
AN→ AN1	1.00	-	-	.70	AN→PN	0.73	.49	.14	.23	
AN→ AN2	0.91	.10	**<.001**	.68	AC→PN	0.53	.43	.22	.18	
AN→ AN3	1.21	.11	**<.001**	.83	IN→PN	0.69	.14	**<.001**	.50	
AC→AC1	1.00	-	-	.76	PBC→PN	0.71	.47	.13	.10	
AC→AC2	0.88	.08	**<.001**	.72	PN					.60
AC→AC3	1.07	.09	**<.001**	.80						
IN→IN1	1.00	-	-	.53	OC→PBC	-0.05	.25	.84	-.02	
IN→IN2	0.98	.16	**<.001**	.61	PBC					.01
IN →IN3	1.43	.21	**<.001**	.77						
PBC→PBC1	1.00	-	-	.48	PN→H	0.17	.02	**<.001**	.52	
PBC→PBC2	1.14	.28	**<.001**	.37	PBC→H	0.78	.20	**<.001**	.34	
PBC→PBC3	1.61	.34	**<.001**	.79	OC→H	0.15	.40	.72	.03	
PN→PN1	1.00	-	-	.79	H					.43
PN→PN2	0.92	.08	**<.001**	.72						
PN→PN3	1.03	.08	**<.001**	.78	IN→INT	0.09	.20	.65	.05	
OC→OC1	1.00	-	-	.35	PN→INT	0.79	.17	**<.001**	.62	
OC→OC2	3.42	.95	**<.01**	.56	PBC→INT	0.58	.75	.44	.07	
OC→OC3	1.64	.63	**<.01**	.47	H→INT	-0.68	.36	.06	-.17	
OC→OC4	1.63	.60	.08	.18	IN					.34
H→H1	1.00	-	**-**	.73						
H→H2	0.88	.09	**<.001**	.61	PBC→BEH	0.45	.17	**<.01**	.26	
H→H3	1.10	.09	**<.001**	.79	OC→BEH	1.15	.47	**<.05**	.30	

H→H4	1.31	.09	**<.001**	.92	INT→BEH	0.01	.01	.28	.07	
H→H5	1.24	.10	**<.001**	.82	H→BEH	0.39	.07	**<.001**	.52	
H→H6	1.27	.09	**<.001**	.90	BEH					.57
INT→INT1	1.00	-	-	.92						
INT→INT2	0.97	.09	**<.001**	.86	AN↔AC	.13	.02	**<.001**	.83	
BEH→BEH1	1.00	-	-	.57	AN↔IN	.14	.03	**<.001**	.46	
BEH→BEH2	1.17	.19	**<.001**	.52	AN↔OC	.01	.01	.17	.15	
BEH→BEH3	0.94	.21	**<.001**	.36	AC↔IN	.15	.04	**<.001**	.43	
BEH→BEH4	1.07	.18	**<.001**	.51	AC↔OC	.01	.01	.48	.07	
BEH→BEH5	1.11	.18	**<.001**	.52	IN↔OC	.01	.01	.68	.04	
BEH→BEH6	0.88	.20	**<.001**	.35						
BEH→BEH7	0.66	.15	**<.001**	.35						
BEH→BEH8	0.88	.20	**<.001**	.35						
BEH→BEH9	0.66	.18	**<.001**	.28						
BEH→BEH10	1.21	.22	**<.001**	.45						

AN= Awareness of Need, AC= Awareness of Consequences, IN= Injunctive Norms, PBC= Perceived Behavioural Control, PN= Personal Norms, OC= Objective Control, H= Habits, INT= Intention, BEH= Behaviour

4.3.5 Testing the extended Comprehensive Action Determination Model

The final model that was tested was the extended version of the CADM that included a variable for environmental identity variable, predicting intentions and behaviour, a variable for biospheric values predicting personal norms and environmental identity, and a variable was included for descriptive norms that also predicted personal norms.

4.3.5.1 Issues with low covariance estimates

When the model was run with all covariances between independent variables (as is common in the SEM literature and was done by Klöckner and Blöbaum), the SEM analysis resulted in an error, as AMOS reported that the covariance matrix was not positive definite. Upon closer inspection of the covariance matrix the covariances between objective control and the other independent variables were found to be close to zero. There are two possible explanations for this. First, as the objective control variable was a binary variable, it may be that the covariance between this variable and the other variables were difficult to estimate. An alternative explanation is that objective control may not have covaried with the other variables. Indeed, it seems unlikely that control over thermostat/lights/radiator/washing machine settings would covary with the participants' biospheric values/awareness of consequences/awareness of need/injunctive norms/descriptive norms.

Although it might seem surprising that this problem was not encountered while running the previous model that also included covariance estimates between objective control and the other independent variables, these covariances were also found to be very low. Perhaps due to the larger number of independent variables in the current model, the low covariance estimates resulted in an error in running SEM for this model whereas the low estimates were still acceptable in the previous model. Therefore, the covariances between objective control and the other exogenous variables in the model were removed from the model and SEM was rerun.

4.3.5.2 SEM analysis results for the extended CADM

The model fit indices showed a slightly reduced model fit compared to the CADM, and a very large increase in AIC, meaning a large decline in parsimony (SRMR:.078, CFI:.874, AIC:1984.90 and RMSEA:.048). The results of the CFA showed that all observed variables were found to significantly load on their respective latent variables, including the fourth objective control item that was previously not found to have a significant load on its latent variable (see Figure 11 and Table 6). Although the environmental identity items did all load significantly on the environmental identity latent variable, the p-values showed that the loadings were not as strong as was the case for other latent variables. This has likely caused the large standard errors in the estimates of the regression coefficients that included the environmental identity latent variable in the structural model (see Table 6).

The structural regression showed that including the environmental identity variable considerably changed the relations between the latent variables in the model. Where in previous models it was found that injunctive norms was the only significant predictor for personal norms, the results of this analysis showed that this variable was solely predicted by environmental identity (B=13.12, p<.05), and together with the six other variables in the model, explained 85% of variance in personal norms, which was 15% higher compared to the CADM. Furthermore, biospheric values significantly predicted environmental identity (B=0.12, p<.05), and could account for 64% of its variance. Habits were again significantly predicted by personal norms (B=0.18, p<.001) and perceived behavioural control (B=0.78, p<.001) and together with objective control these variables explained 43% of the variance in habits. In turn, habits (B=-0.73, p<.05) and personal norms (B=1.40, p<.001) were found to significantly predict intention, and together with the other variables in the model accounted for 38% of the variance. Finally, objective control (B=0.99, p<.05), perceived behavioural control (B=0.47, p<.01) and habits (B=0.35, p<.001) significantly predicted behaviour and together with intention and environmental identity (that did not significantly predict behaviour) explained 52% of the variance, which is a reduction of 5% in comparison with the CADM. The reduction in explained variance can be attributed to the addition of the variables as this adjusted R-square variable corrects for the number of predictors. Furthermore, strong correlations were found between injunctive norms and descriptive norms (r=.90) and awareness of need and awareness of consequences, as in previous models (r=.83).

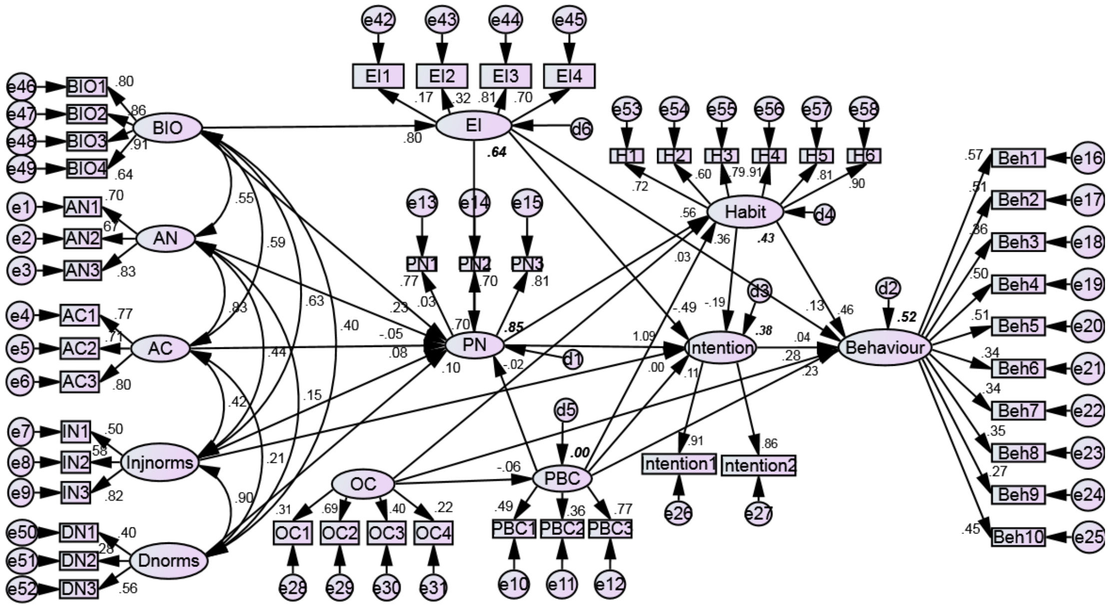

Figure 11: SEM results for the extended CADM with standardised regression coefficients shown

Table 6: Detailed results from SEM analysis of the extended CADM

Measurement model					**Structural model**					
Model Link	***B***	**S.E.**	***p***	**Beta**	**Model Link**	***B***	**S.E.**	***p***	**Beta**	**R^2**
BIO→BIO1	1.00	-	-	.80	BIO→PN	0.10	.58	.86	.03	
BIO→BIO2	1.08	.07	**<.001**	.86	AN→PN	0.72	.89	.42	.23	
BIO→BIO3	1.14	.07	**<.001**	.92	AC→PN	-0.13	.49	.79	-.05	
BIO→BIO4	0.89	.09	**<.001**	.64	IN→PN	0.12	1.09	.92	.08	
AN→ AN1	1.00	-	-	.70	PBC→PN	-0.12	.36	.74	-.02	
AN→ AN2	0.90	.10	**<.001**	.67	DN→PN	0.21	1.32	.88	.10	
AN→ AN3	1.21	.11	**<.001**	.83	EI→PN	13.12	5.67	**<.05**	.70	
AC→AC1	1.00	-	-	.77	PN					.85
AC→AC2	0.86	.08	**<.001**	.71						
AC→AC3	1.06	.09	**<.001**	.80	BIO→EI	0.12	.05	**<.05**	.80	
IN→IN1	1.00	-	-	.50	EI					.64
IN→IN2	1.01	.16	**<.001**	.58						
IN →IN3	1.63	.23	**<.001**	.82	OC→PBC	-0.16	.28	.58	-.06	
DN→DN1	1.00	-	**-**	.40	PBC					.01
DN→DN2	0.78	.24	**<.01**	.29						
DN→DN3	1.45	.31	**<.001**	.56	PN→H	0.18	.02	**<.001**	.56	
EI→EI1	1.00	-	**-**	.17	PBC→H	0.78	.19	**<.001**	.36	
EI→EI2	1.88	.84	**<.05**	.31	OC→H	0.20	.42	.64	.04	
EI→EI3	6.76	2.70	**<.05**	.81	H					.43
EI→EI4	5.09	2.05	**<.05**	.70						
PBC→PBC1	1.00	-	-	.49	EI→INT	-11.67	7.78	.13	-.49	
PBC→PBC2	1.09	.27	**<.001**	.36	IN→INT	-0.01	.21	.98	-.01	
PBC→PBC3	1.54	.34	**<.001**	.78	PN→INT	1.40	.41	**<.001**	1.09	
PN→PN1	1.00	-	-	.77	PBC→INT	0.94	.81	.24	.11	
PN→PN2	0.91	.08	**<.001**	.70	H→INT	-0.73	.37	**<.05**	-.19	
PN→PN3	1.09	.08	**<.001**	.81	IN					.38
OC→OC1	1.00	-	-	.31						
OC→OC2	4.80	1.88	**<.05**	.69	EI→BEH	0.59	.49	.23	.13	
OC→OC3	1.63	.56	**<.01**	.40	PBC→BEH	0.47	.17	**<.01**	.28	
OC→OC4	0.89	.42	**<.05**	.22	OC→BEH	0.99	.47	**<.05**	.23	
H→H1	1.00	-	**-**	.72	INT→BEH	0.01	.01	.50	.04	
H→H2	.88	.10	**<.001**	.60	H→BEH	0.35	.08	**<.001**	.46	
H→H3	1.10	.09	**<.001**	.79	BEH					.52
H→H4	1.31	.09	**<.001**	.91						
H→H5	1.24	.10	**<.001**	.81	AN↔BIO	.08	.01	**<.001**	.55	

H→H6	1.27	.09	**<.001**	.90	AN↔AC	.13	.02	**<.001**	.83
INT→INT1	1.00	-	-	.91	AN↔IN	.13	.03	**<.001**	.44
INT→INT2	0.99	.09	**<.001**	.86	AC↔IN	.14	.03	**<.001**	.42
BEH→BEH1	1.00	-	-	.57	AC↔BIO	.10	.02	**<.001**	.59
BEH→BEH2	1.17	.20	**<.001**	.52	IN↔BIO	.20	.04	**<.001**	.63
BEH→BEH3	0.95	.21	**<.001**	.36	DN↔BIO	.09	.03	**<.01**	.40
BEH→BEH4	1.07	.18	**<.001**	.50	DN↔AN	.03	.02	.18	.15
BEH→BEH5	1.11	.19	**<.001**	.51	DN↔AC	.05	.03	.07	.21
BEH→BEH6	0.88	.21	**<.001**	.34	DN↔IN	.42	.10	**<.001**	.90
BEH→BEH7	0.66	.15	**<.001**	.34					
BEH→BEH8	0.88	.20	**<.001**	.35					
BEH→BEH9	0.65	.19	**<.001**	.27					
BEH→BEH10	1.22	.23	**<.001**	.45					

BIO= Biospheric values, AN= Awareness of Need, AC= Awareness of Consequences, IN= Injunctive Norms, DN= Descriptive norms, EI= Environmental Identity, PBC= Perceived Behavioural Control, PN= Personal Norms, OC= Objective Control, H= Habits, INT= Intention, BEH= Behaviour

4.4 Discussion

4.4.1 Interpretation of the findings

4.4.1.1 Evaluating model fit

This study aimed to replicate the study by Klöckner and Blöbaum (2010) by testing if the CADM and an extended version of the CADM provided a superior fit over previous models for energy saving behaviour. In the following section, the model fit across the different models will be evaluated based on the model fit indices and the percentages of explained variance that the models could account for.

Inspecting the model fit indices, each model seemed to reasonably fit the data, yet not a single model stood out by scoring best on all model fit indices (see Table 7). The TPB produced the best SRMR and AIC indices as these were the smallest values across the various models. The model that combined the TPB and the NAM resulted in the highest CFI index and was therefore the best model according to this index. The CADM was only found to perform best according to the RMSEA as this model produced the lowest value on this index. Therefore, the model fit indices did not provide a clear picture as to which model best fitted the data. Based on these indices, the TPB seemed to be the best model as it is the simplest model and (therefore) has the best SRMR and AIC values. Furthermore, the addition of the variables in the extended version of the CADM did not improve model fit, but showed a slightly poorer fit, indicated by all the fit indices compared to the CADM. However, it needs to be noted that, with the exception of the AIC, there is not a large variation among the values of the different model fit indices across the different models. Because there is not one single method within SEM to compare model fits, but the comparison of the fit of various models involves the consideration of a range of model fit indices, these results show that all the models fit the data reasonably well but not a particular model fits the data much better than the other models. Furthermore, although the CADM fitted the data well according to these model fit indices, the model fit was not as good as in previous applications of the model (Klöckner & Blöbaum, 2010; CFI = .99, RMSEA = .03, SRMR = .03; Klöckner, 2013; CFI= .97, RMSEA= .071, SRMR= .023).

Table 7: Model fit indices for each tested model

	Fit criteria	**TPB**	**NAM**	**TPB+NAM**	**CADM**	**Extended CADM**
SRMR	<.10	.0678	.074	.0745	.072	.078
CFI	>.90	.876	.90	.909	.899	.874
AIC	Closest to 0	310.21	546.80	620.79	1200.45	1984.90
RMSEA	<.06	.055	.05	.048	.047	.048

Note: SRMR= Standardized Root Mean Square Residual, CFI= Comparative Fit Index, AIC= Akaike Information Criterion RMSEA= Root Mean Square Error of Approximation, TPB= Theory of Planned Behaviour, NAM= Norm Activation Model, CADM= Comprehensive Action Determination Model.

Another way to assess how well the models predicted energy conservation is to compare the percentage of explained variance in the latent variables of the models (see Table 8). With this approach, the TPB proved to be the weakest among the other models as it explained the least amount of variance in intention and behaviour. Furthermore, the TPB, NAM and TPB+NAM models in this study explained 32-38% of variance in behaviour, which is considerably less compared to the study by Klöckner & Blöbaum (2010) that explained 54-59% of variance in behaviour with these models. The current results showed that the CADM was the most successful model in terms of explaining variance in behaviour, as it explained 57% of variance, which is less than Klöckner & Blöbaum's 65%, but much higher than the 35% of variance that could be explained in a meta-analytical structural equation model evaluation that compiled various environmental behaviours (Klöckner, 2013). Furthermore the CADM accounted for an adequate amount of variance in personal norms, habits and to a lesser extend intention. Although the extended CADM explained less variance in behaviour (as this statistic corrected for the number of independent variables), it was better at explaining variance in personal norms compared to the other models, due to the inclusion of environmental identity.

Table 8: Explained variance of latent variables for each model

	TPB	NAM	TPB+NAM	CADM	Extended CADM
Environmental identity	-	-	-	-	64%
Habit	-	-	-	43%	43%
Perceived behavioural control	-	-	-	0%	0%
Personal norms	-	59%	59%	60%	85%
Intention	17%	-	33%	34%	38%
Behaviour	32%	35%	38%	57%	52%

Note: TPB= Theory of Planned Behaviour, NAM= Norm Activation Model, CADM= Comprehensive Action Determination Model.

The two types of model-evaluation approaches did not result in a coherent conclusion in terms of the superiority of any of the models over the other. All of the models fitted the data reasonably well according to the model fit indices and the CADM model explained the most variance in energy saving behaviour. Hence, the CADM was successfully applied to energy conservation behaviour, thereby extending it beyond travel behaviour and showing it has value in explaining other types of environmental behaviour. The extended CADM did not result in a better model fit or more explained variance in behaviour, suggesting that the addition of the variables did not improve the model. That is, in both models, the only factors that could significantly predict behaviour were habits, perceived behavioural control and objective control. The additional variables did not significantly predict behaviour, and therefore the extended model did not explain more variance in behaviour compared to the CADM. However, the inclusion of the additional variables did strongly increase the explained variance in personal norms and environmental identity in the extended model. Therefore, models that aim to predict personal norms and environmental identity (such as the NAM) could benefit from including biospheric values and environmental identity into the model.

4.4.1.2 Evaluating the model links

The regression parameter estimates for the five models revealed a couple of interesting patterns. First, the CADM and extended CADM showed a clear intention-behaviour gap as intention could not significantly predict behaviour in these models. This is in line with previous research that has found that behaviour often does not follow from intentions (Armitage & Conner, 2001; Bamberg & Schmidt, 2003; Randall & Wolff, 1994; Sheeran & Orbell, 1998). However, in the other two models, intention could (just) significantly predict behaviour and this discrepancy was likely due to the addition of the other variables in the CADM models that were better able to predict behaviour. This is consistent with previous research that found that energy habits were more predictive of frequent energy behaviours than intensions to conserve residential energy (Macey & Brown, 1983).

Second, as discussed above, the inclusion of environmental identity in the model increased the explained variance in personal norms although it could not predict intentions or behaviour. Only one other study has confirmed this link between environmental identity and personal norms that focused on electric car purchase (Barbarossa et al., 2015), yet no such relation has been found in energy consumption. The concept of environmental identity has only recently been introduced (e.g. Gatersleben et al., 2012) and these results suggest that this variable has great potential to improve models that include personal norms (e.g. the NAM or Value Belief Norm Model).

Furthermore, biospheric values could account for 64% of the variation in environmental identity. This means that a person's concern for the environment strongly influences the extent to which they perceive environmentalism to be central to who they are, and this finding is in line with previous research (Gatersleben et al., 2012). However, biospheric values have also been found to modestly predict personal norms (Nordlund & Garvill, 2003), which was not confirmed in this study as this link was not found to be significant. This disparity could be attributed to the differences in the measurement of this construct. Nordlund and Garvill measured value-orientation using Thompson and Barton's (1994) eco-centric environmental value-orientation scale that is more emotion focussed (items include "*It makes me sad to see natural environments destroyed*" and "*Sometimes when I am unhappy I find comfort in nature*") compared to the scale used in this study by Steg and colleagues (2012). The latter scale does not make any explicit links to personal emotions as it asks participants how they value various aspects of the environment (e.g. "*respecting the earth*", "*protecting the environment*" etc.).

Because personal norms reflect a person's perceptions of their moral obligation to engage in pro-environmental behaviour, it is likely that feelings of moral obligation are more strongly influenced by affective relations to the environment than more abstract and rational evaluations of the environment which can explain why no relation was found in the current study. Furthermore, the non-significant relation between biospheric values and personal norms in this study is also in contrast with the findings of the meta-analytic structural equation model of the CADM, in which self-transcendent values (which correspond to biospheric values; Schultz, 2005) were found to be moderately correlated to personal norms. Because these correlations were not found to be strong in the meta-analytic study, it is likely that the inclusion of the link between environmental identity and personal norms has partialled out the common variance between biospheric values and personal norms in this study, considering that biospheric values significantly predicted environmental identity and therefore these two variables also shared variance.

Although previous research has often found a robust link between descriptive norms and environmental behaviour (e.g. Cialdini et al., 1990; Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007; Schultz, Khazian, & Zaleski, 2008), the inclusion of descriptive norms was not found to improve the model. It was hypothesised that descriptive norms influence personal norms, yet this link was found to be insignificant. Interestingly, the injunctive norm variable was able to predict personal norms in all models except for the last model that also included descriptive norms, suggesting that descriptive norms shared variance with injunctive norms. Indeed, injunctive norms and descriptive norms were found to correlate extremely highly, suggesting that perhaps, these two concepts are too closely related and do not both need to be included in the model.

Another noteworthy aspect of the CADM and extended CADM is that no statistically significant relation was found between objective control and perceived behavioural control (PBC). Nevertheless, Klöckner & Blöbaum (2010) did find that objective control significantly and strongly predicted PBC. This may be due to the fact that these two variables were measured on different levels of specificity regarding behaviour in the current study. That is, PBC was measured in terms of general energy use whereas the objective control items asked participants about their control over settings of specific devices. It is possible that participants' feeling of control over energy use was not dominated by the control over these devices but determined by other factors such as weather conditions or the insulation of the house, which would explain the insignificant relation between these variables.

The findings of this study provide an insight into the nature and antecedents of energy behaviour. Most of the variance in energy saving behaviour could be explained with the CADM as opposed to the traditional models of the TPB and NAM. This model's advanced ability to predict energy saving behaviour can be attributed to the inclusion of habits and objective control that were not included in these previous models and were found to have a very strong relation with behaviour, much stronger than the TPB variable intention or the NAM variable of personal norms. These findings therefore suggest that contextual factors are extremely important in understanding energy behaviour. Previous environmental behaviour models assumed that behaviour is intentional and that these intentions are formed through a conscious process in which people weigh the consequences of the behaviour and the normative context of the behaviour (Ajzen, 2002). However, the findings of this study suggest that the opposite may be true for energy behaviour: this behaviour is unrelated to intentions, and strongly driven by habits and the perceived and objective ability to control energy consumption. The study discussed in Chapter 3 suggested that people perceive a particularly strong influence of social norms on their energy behaviour, which link has not been confirmed in the current study because the normative processes predicted intentions, but intentions did not predict behaviour.

This discrepancy suggests that people might not be aware of the most important factors that influence their energy behaviour.

The majority of energy behaviour takes place in stable contexts (homes) where strong energy habits can be developed and this study suggests that people might have little influence on breaking these habits. Indeed, habits have consistently been found to be very relevant to energy use (Macey & Brown, 1983; Maréchal, 2010) as energy behaviour is context dependent, automatic and frequent (Verplanken & Aarts, 1999). Furthermore, the strong influence of perceived and objective control on behaviour in this model are likely to be unique to energy behaviour in particular due to the strong context-dependency of the behaviour. However, it needs to be noted that these findings are likely to apply to individuals in stable contexts, i.e. people who tend to consistently live in the same household. Disrupted contexts may result in the behaviour being more dependent on intentional processes.

Although previous models may have focussed too much on normative processes and the rational perception of the consequences of the behaviour to explain energy use, the findings of this study do show that these processes still play an important role. That is, personal norms and PBC predicted habits. These personal norms in turn, were mainly influenced by injunctive norms, and in the extended model by environmental identity, suggesting that these variables are still very relevant to consider in relation to energy behaviour as they precede the habitual factors that have a direct influence on behaviour.

4.4.2 Evaluation of methods and the CADM

The findings of this study need to be interpreted in light of the strengths and weakness of the methods used in this study. Therefore, the following sections will cover the issues that have arisen in the measurement of the constructs in this study, a critical discussion of the use of SEM and finally the use of the CADM will be discussed in relation to the study that first introduced the model.

4.4.2.1 Measurement complications

There are various limitations of the measurements in this study that need to be considered. First, energy saving behaviour was measured using items that asked participants about their energy saving behaviour over the previous week. Reporting on past behaviour instead of current or future behaviour is more likely to reflect actual behaviour and may mitigate biases associated with self-report measures (Gatersleben, 2013). However, various authors have warned that predicting past behaviour from future intentions is problematic (Abrahamse, Steg, Gifford, & Vlek, 2009; Steg & Nordlund, 2013). Nevertheless, retrospective behaviour has been successfully predicted from current intentions in some studies (Harland, Staats, & Wilke, 1999; Heath, 2002). In the current study, future intention could predict past energy saving behaviour in the models that did not include habits and objective control to predict behaviour. Hence, this limitation of the measurement of behaviour does not impose a major threat to the validity of the measure.

Moreover, the measure of energy behaviour only consisted of better management energy behaviour ("*Putting a lid on a saucepan when boiling water*") and curtailment of comfort behaviour ("*Wearing a jumper instead of turning up the radiator when I'm cold*"). This means that no measures of efficiency investments (e.g. purchasing energy saving light bulbs) were included, which is likely to have affected the findings in this study. That is, efficiency investments that involve large financial investments or effort (e.g. installing insulation) are more likely to be a result of elaborate thought processes, and therefore intentions. Hence, habits may have been less predictive of energy behaviour if such behaviour would have been included in this study. However, the energy behaviour in this study was to convey daily energy behaviour to maximise the utility of the model, and therefore these behaviour were not included in the current study.

An important issue in behavioural modelling is the '*Principle of Compatibility*' (Ajzen & Fishbein, 1977) that stresses that constructs can only predict behaviour when the constructs are measured specific to the particular behaviour. All the variables measured for the first four models complied with the principle of compatibility, yet biospheric values and environmental identity were measured in relation to general environmental behaviour. Although it may be difficult to specify biospheric values to energy behaviour, this study could have benefited from measuring environmental identity in relation to energy use (e.g. "*I would be embarrassed to be seen as having an energy saving lifestyle*"). It needs to be noted that despite lacking compatibility, this variable was very good at predicting personal norms that were specific to energy use. This therefore suggest, that perhaps this was not a major issue in this study, yet, it would still be recommended that when environmental identify is incorporated in future models it is measured in relation to the specific (environmental) behaviour.

Finally, it is generally recommended to use continuous observable variables in SEM (Ullman, 2013). However, the items measuring objective control only had two answer responses due to the nature of these questions (as control over settings on a washing machine/thermostats/radiator/lights is likely to be all-or-nothing). Although Maximum Likelihood (MLE) can be applied to dichotomous variables (Skrondal & Rabe-hesketh, 2005), if the observable variables for objective control would have been continuous this could have aided the accuracy of the parameter estimates as the multivariate normality assumption for MLE is more likely to hold (Ullman, 2013). This could perhaps result in a significant relation between objective and perceived behavioural control and habits as the CADM hypothesises, but was not confirmed in this study.

4.4.2.2 Notes on the use of SEM

One of the most important advantages of SEM over alternative approaches such as multiple regression or mediation analysis is that it is unique because it simultaneously tests the links between variables, by producing regression coefficients, and evaluates the entire model, using different evaluative statistics that test various aspects of the model (Ullman, 2013). This is extremely useful when comparing various models and assessing how the variables within the model relate to each other, as was the aim in this study. Another advantage of SEM is that it also allows for the inclusion of latent variables for constructs that cannot be measured directly and performs CFA to test the loadings of the observed variables on the latent variables. SEM therefore produces the CFA statistics as well as the structural regressions statistics that could not have been obtained in one analysis with alternative methods. Because SEM produces such a detailed account of the model and covers various aspects of the model, this method was the best statistical method to evaluate the models in this study. Nevertheless, the application of SEM to the data in this study did reveal a number of shortcomings of the technique.

First, the negative error variance that was reported in the analysis of SEM to the TPB (see 4.3.1.1) flagged a major limitation of the SEM method. This situation is known as a Heywood case, which implies an improper solution that could indicate a number of different issues with the model (Kolenikov & Bollen, 2012). To date, there is no method available to assess the causes of the Heywood case and the author is left to speculate what caused the improper solution. As for resolving this issue, again, there is no consensus in the literature as different solutions are proposed and recommended. For example, one alternative solution is to use unweighted least square estimations (ULSE) instead of MLE (McDonald, 2014). However, ULSE has major disadvantages such as its scale dependence and limited number of model fit indices and standard errors not being reported in the output (Blunch, 2013; Bollen, 1989; Norman & Streiner, 2003), and the parameter estimates differed quite a bit when the models were rerun with ULSE.

However, the solution chosen in this chapter was not without its own limitations either. When restraining a negative error variance to 0, one relies on the assumption that the negative error variance is due to sampling error and thereby imposing a value on the variance which may not be the true variance value. If this assumptions is not true, this may invalidate the model estimation. As Heywood cases are common in SEM (Kolenikov & Bollen, 2012), a consensus on an appropriate method to manage these issues is needed. Without such a consensus, authors are left to pick and choose their preferred method which is likely to result in disparity in methods and results among SEM applications.

Another limitation for which SEM is often criticised in the literature is the large number of indices that are required for the model evaluation. Although various authors offer critical evaluations of the model fit indices (e.g. Blunch, 2013; Byrne, 2010; Kline, 2005), all the indices have their limitations, and the researcher is left to select which indices are to be used to evaluate the model. This leaves the method susceptible to a form of data dredging where authors can pick the model fit indices that indicate a good model fit and fail to report ones that contradict this conclusion.

From this discussion, it is clear that SEM suffers from methodological uncertainty in terms of the assumptions that need to be met, the causes and resolutions to improper SEM solutions and the selection of model fit indices. SEM is a relatively new technique and although it has gained popularity in recent years, it needs to be explored in more detail so that recommendations on the application of the method are more consistent across literature. This would increase the consistently of the applications of SEM and thereby the ability to compare the results across different applications of SEM.

4.4.3 Evaluating the CADM

The CADM can be commended for extending psychological models that have previously dominated the field of environmental psychology that were limited in their focus on intentional or normative variables to explain behaviour. The model construes behaviour as a result of these variables of norms and intentions but also acknowledges the (facilitating or hindering) role that habitual and situational processes can play in the translation of behavioural intentions into behaviour. This model therefore provides a fuller account of behaviour by both including variables that capture people’s conscious choices as well as the unconscious influences on their behaviour. The CADM is therefore particularly valuable in terms of explaining behaviours that are dependent on the context in which the behaviour takes place and especially when behaviour is very habitual which influences the likelihood of intentions to result in behaviour.

Therefore, the CADM was particularly successful in accounting for energy behaviour in this study, as energy behaviour is context dependent and often of habitual nature. Indeed, previous studies that have applied the model to other habitual behaviour such as travel mode choice (Klöckner & Blöbaum, 2010) and recycling (Klöckner & Oppedal, 2011), have also found that the model can successfully predict behaviour. Specifically, Klöckner and Oppedal (2011) found that the CADM explained more variance in recycling behaviour of specific items rather than recycling in general. The CADM may have been more successful in accounting for recycling of specific items as it is more likely to involve strong habits and the recycling of these specific items was found to be strongly dependent on the recycling scheme of the specific recycling faction, thus the situational factors (Klöckner & Oppedal, 2011).

Moreover, an application of the CADM to behaviours that are less likely to be habitual or occur in a stable context such as the adoption of new heating systems was much less successful (Sopha & Klöckner, 2011). Furthermore, the poor results of the meta-analytic structural equation model evaluation on various environmental behaviours may have been due to the inclusion of environmental behaviours that are not of habitual nature and are not strongly influenced by situational processes such as car purchase, switching electricity provider, green tourism and environmental activism (Klöckner, 2013). The differences in the success of the application of the CADM in these studies therefore further underline that the CADM is particularly useful in predicting environmental behaviours that are habitual and context dependent but perhaps less able to explain environmental behaviours that are one-off investments that may require more conscious processes, which may also differ across energy behaviours as discussed above.

The CADM shows a clear strength in explaining some environmental behaviours that previous models have not been able to predict with as much success. However, the application of the CADM to energy behaviour in this study also highlighted various weakness of the model, methods and the study that first introduced this model. First, Klöckner and Blöbaum (2010) did not include any model fit indices that reflected the parsimony of the model. The current study showed, not surprisingly, that the parsimony model fit indices demonstrated an incrementally worse model fit from the first to the last model, showing that the CADM is less parsimonious than the TPB and NAM. By not including a parsimony model fit index, the model fit of the CADM appears to be superior over the TPB and NAM but ignores an important dimension on which the CADM is not superior over the other two models: the complexity of the model.

Second, Klöckner and Blöbaum (2010) implicitly assumed that all the exogenous variables in the model covaried and therefore included covariance relations between all of these variables. The decision to covary all exogenous variables does not seem to be based on previous literature nor was a justification for this discussed. Although covariance can logically be expected between variables such as awareness of consequences and awareness of need, accounting for covariation between objective control and awareness of need or awareness of consequences may be difficult to justify. That is, why would someone with more control over their environmental behaviour be expected to have a better understanding of the consequences of their behaviour and the need for changing this behaviour? Indeed, Klöckner and Blöbaum (2010) did not find objective control to significantly covary with awareness of need and awareness of consequences, and only weak covariances between objective control and the other independent variables were reported, similar to the findings in this study. Moreover, when objective control was covaried with the other independent variables in the extended version of the CADM this resulted in an improper solution because the covariance between these variables was very low. Therefore, including these covariances in the model seems unjustified. Perhaps these links were included in the original study to optimise model fit, as not including them implies zero covariance between the variables. Indeed, when the CADM in this study was rerun without the covariance links between objective control and the other independent variables, the model fit was slightly weaker. However, including covariance relations where they cannot be logically expected or based on previous literature, should not be permitted as this seems to be an unjustifiable method to obtain statistical support for the model.

Another issue with the CADM model that became apparent in this chapter is the inconsistency in model specification by Klöckner across different publications. First, although attitudes were included when the CADM was first introduced, this variable was not included when the model was tested in the same publication (Klöckner & Blöbaum, 2010). Second, there are a lot of inconsistencies in model specification across the different applications of the CADM. For example, the meta-analytic structure equation model (Klöckner, 2013) also included the new environmental paradigm, self-transcendence values and self-enhancement values. Furthermore, in an application of the CADM to recycling behaviour, the objective control variable was omitted from the model (Sopha, Klöckner, & Hertwich, 2011). A more detailed discussion of the inconsistencies in model specification of the CADM is discussed in the work by Thomas (2014). The inconsistencies in the model specification are not addressed by Klöckner in any of these publications and, again, the justification for this is unclear. Without the consistent application of the CADM across different behaviours, there is no clear picture on what constitutes the CADM, and how well it predicts behaviour. Perhaps the differences in the model were introduced to better fit the behaviour to which the model was applied, yet the validity of this is ambiguous as again, it seems that this is a way to improve the model fit of the CADM to any data to gain support for the model.

Finally, the original publication of the CADM used a limited number of items to measure each latent variable. That is, most constructs were measured with three items and some even with as little as two, even though literature on SEM consistently recommends using a minimum of four items to measure latent variables (Blunch, 2013; Kline, 2005; Schumacker & Lomax, 2010). Using less than four items can result in Heywood cases, which was likely to have been the case in the application of the TPB in this study (see 4.3.1.1). Furthermore, Klöckner and Blöbaum (2010) reported to have selected the items that resulted in the highest internal consistency in a pilot study. Items that were less consistent with the other items may not necessarily reflect less valid measures of the construct, but merely a more complex and therefore realistic representation of the construct. Excluding these items may result in an over simplification of the model that may optimise model fit at the expense of the accuracy of the parameter estimates within the model (Ding, Velicer, & Harlow, 1995; Marsh, Hau, Balla, Grayson, & Is, 1998). In fact, Kline (2005) argued that the focus with SEM should not be on model fit but instead on the relations within the model suggesting that SEM applications may benefits from a larger number of measurements for the latent variables. Therefore, perhaps all the original items should have been included as this may have resulted in a more valid test of the model.

4.4.4 Future research directions

The application of the CADM to energy saving behaviour has highlighted various difficulties with the use of SEM as well as with the model itself, from which a number of recommendations can be drawn for future studies that will use similar methods with similar aims. First, where possible, the items measuring the observable variables should be measured on a continuous scale to increase the accuracy of the parameter estimates. Furthermore, sufficient items should be used to measure each construct as failing to do so can result in Heywood cases which is problematic for the analysis and for which there is no clear solution. The validity of the measures could also be enhanced by measuring actual energy consumption rather than relying on self-report data. Measuring real energy behaviour would strongly increase the validity of the measure and it would be interesting to see if an equally or higher amount of variance could be explained when taking a direct measure of behaviour. Considering the variation in model specification across the different applications of the CADM, a consistent model specification is clearly needed to allow for comparison across the different studies.

Not only can future studies take these methodological improvements into account, the findings of this study also suggest a couple of promising theoretical avenues for future research. Although the CADM originally included attitudes, this factor was not included in the test of the CADM in this study, following Klöckner and Blöbaum (2010). Considering the relevance of energy conservation attitudes to energy behaviour (see section 2.3.4.1), future research could test a CADM that includes attitudes on energy conservation to investigate the role of this variable within the model. Furthermore, this study highlighted the important role of environmental identity in energy behaviour and in predicting personal norms in particular. A strong link between biospheric values and environmental identity has also been identified, and therefore these variables could be integrated into relevant existing models. Finally, this study suggests that the CADM is successful in predicting energy behaviour, which is likely due to the habitual nature of energy consumption and the strong influence of contextual factors. This hypothesis could be tested in future research by applying the model to other behaviours or experimentally manipulating the habitual and contextual nature of the behaviour to assess any differences in the application of the model.

Furthermore, it is likely that not all energy behaviours are as strongly dependent on habits, and may therefore not be predicted as well by the CADM compared to the daily energy curtailment behaviours that were predicted in this study. Indeed, efficiency investments may be more likely to be a result of elaborate and rational processes, and are therefore likely to be determined by very different factors. As discussed in Chapter 1, these types of energy behaviours are expected to be strongly influenced by people's knowledge about domestic energy use, rather than habitual processes. Therefore the second part of this thesis will further investigate energy literacy to provide a comprehensive account of the antecedents of various energy behaviours.

4.4.5 Conclusion

In short, this study showed that the CADM could be successfully applied to energy saving behaviour, thereby extending its earlier use in quite a different context. The success of the application is likely due to the inclusion of habitual and situational processes in the CADM. Furthermore, the inclusion of environmental identity and biospheric values resulted in a very good prediction of personal norms in an extended version of the CADM, although the models ability to predict behaviour was not improved with the addition of these variables. Moreover, methodological inconsistencies and ambiguity in both applications of SEM and the CADM call for more consensus on the assumptions and application of SEM.

Chapter 5: Reviewing the Literature on Energy Literacy

Most of the research that has investigated energy behaviour tends to focus on motivational factors that underpin energy conservation whereas the impact of the behaviour is often neglected. To engage in efficient energy saving behaviour people need to have a good understanding of the energy use in their household. Therefore, this chapter will review the literature on energy literacy: people's understanding of energy consumption. This concept has been operationalised in various ways; ranging from people's understanding of home temperature controllers, the accuracy of the energy judgements of household appliances, the accuracy of the perception of the relative impact of energy saving activities, the ability to evaluate the economic benefits of energy efficiency investments, and a scientific understanding of energy generation and consumption. The literature on each type of energy literacy was critically reviewed and gaps in the research were identified. This chapter concludes with an evaluation of which type of energy literacy is likely to be most promising to directly relate to energy saving behaviour and will therefore be the focus of the remainder of this thesis.

5.1 Introduction

Imagine a man named John who lives in a large house in a suburb of a medium sized town. John is aware of the adverse impact of energy consumption on the environment and feels responsible to take action. John believes that saving energy is the right thing to do and is therefore in the habit of switching off the lights when he leaves the room and makes sure his appliances are not on stand-by to save energy for the environment. However, John uses his tumble dryer weekly and frequently uses the oven to prepare meals. As seen in Chapter 4, John would likely score positively on all of the constructs of the Comprehensive Action Determination Model (CADM) (e.g. strong personal norms, awareness of consequences, intentions). Furthermore, the model would probably predict energy consumption quite accurately if energy conservation would be measured in terms of the frequency of energy saving behaviours.

Now imagine Sarah, who lives in a small flat with a pre-payment meter. She is not sure how energy consumption affects the environment and is not very concerned about environment problems. Sarah feels that it is not her responsibility to conserve energy and does not feel like her social environment does either. Nonetheless, because she has a low income, she watches her energy consumption carefully and does not own a tumble dryer. When she uses the oven she prepares several meals at once and never puts her thermostat higher than 19 degrees as she knows heating her flat costs a lot of money. Applying the CADM to Sarah's situation, she is likely to score low on constructs such as social norms and energy saving attitudes, yet Sarah consumes less energy than John.

This example highlights a crucial weakness of the CADM: it does not take the impact of the energy conserving behaviour into account when studying the factors that affect this behaviour. Sarah is aware of the energy consumption in her household and therefore saves energy more efficiently than John who seems to only engage in token energy saving behaviours to feel like he has 'done his part' for the environment. This example shows that both motivation to save energy as well as knowledge about how to save energy is crucial to result in effective energy conservation behaviour. That is, when investigating energy saving behaviour, the focus should not solely be on *why* people would be willing to save energy, but also *how* people think about ways to save energy. Similarly, appeals aimed at behaviour change in the health domain have been found to be most effective when not only designed to enhance motivation to adopt more healthy behaviours, but also to increase the recipient's efficacy to identify ways to adopt more health behaviour (Witte & Allen, 2000).

Furthermore, although the CADM was found to successfully predict energy consumption in the last chapter, only curtailment behaviours were predicted in that study and it is unlikely that the model would predict efficiency investment behaviours as accurately. That is, some energy behaviour may be less habitual and more strongly determined by intentions to save energy, such as when householders consciously decide to save energy by investing effort or money into the energy efficiency in their home. These behaviours are more likely to be a result of people's understanding of the energy use in their home, meaning their energy literacy. The CADM factors of perceived and actual control may be closely related to the understanding of energy use but these factors are distinct from energy literacy as they do not reflect the accuracy of energy perceptions, but rather whether an individual feels like he can save energy which may or may not be influenced by their perceived knowledge of energy saving behaviour. Therefore, to provide a comprehensive account of the antecedents of various types of energy behaviours, the following chapters will focus on energy literacy, which is likely to determine efficiency behaviours and the impact of people's energy saving behaviours.

A model that emphasises the importance of people's knowledge of energy consumption for optimal energy saving behaviour is the Information Deficit Model (Wilhite & Ling, 1995, see Figure 12). The Information Deficit Model assumes that a lack of energy conservation among householders can be ascribed to a deficiency of people's awareness of how to save energy in their home or energy related issues. Therefore, it assumes that increased feedback on energy consumption, will enhance householders' awareness of their energy consumption and thereby their knowledgeable on ways to save energy that translates into changes in residential energy use resulting in a reduction in energy consumption (Wilhite & Ling, 1995).

Figure 12: The information Deficit Model by Wilhite & Ling (2005)

Initial qualitative findings by the same authors seemed to support the model (Wilhite & Ling, 1995), however, it excluded the influences of driving factors that, as was seen in the former chapters, can have a strong influence on energy consumption. That is, the model assumes that householders are already motivated to save energy but lack the knowledge to translate this motivation into behaviour. Therefore, an integration of both models is needed to account for all energy conservation behaviour adequately, as proposed in the multiplication model of energy literacy and energy saving drivers introduced in Chapter 1. What is needed, in other words, is a model that encompasses both people's drivers to act *and* their ability to act (for a further discussion see Chapter 9).

Qualitative studies on general energy perceptions have shown that energy is perceived as intangible and an abstract concept, and people might lack a coherent mental model on what constitutes energy due to the 'hidden' nature of energy (Chisik, 2011; Pierce & Paulos, 2010). A concept that investigates these perceptions more specifically is energy literacy: the accuracy of people's understanding of household energy consumption. Energy literacy is highly likely to influence the decision making process when consumers intend to save energy. In other words, the extent to which energy-saving behaviours indeed save energy, will be related to the person's knowledge of how consumptive those behaviours are. Energy literacy has been studied in a number of fields (e.g. education, economics, psychology) within which the term has been conceptualised differently, or sometimes is not defined at all. Each type of energy literacy sets different requirements to classify a person as 'energy literate'. An energy literate person can be someone who knows how their home heating system works, knows how to save energy in their home, knows how to make economic energy efficient decisions or knows about the relation between energy use and climate change. This means that an individual can be energy literate according to one definition of energy literacy, but not according to a different conceptualisation of energy literacy.

The aim of this literature review was to summarise the literature on the different operationalisations of energy literacy. The various definitions of energy literacy found in the literature are grouped and discussed in order of inclusiveness, starting with the most specific type of energy literacy and finishing with the most encompassing definition of energy literacy. As such, this chapter will critically review the literature on people's mental models of home heat control, people's understanding of the energy consumption of domestic appliances, their knowledge of energy saving behaviour, the understanding of economic aspects of energy use, and their scientific understanding of energy consumption, which tends to encompasses a combination of the former types of energy literacy. This chapter will close with a comparison and evaluation of the different definitions of energy literacy and a conclusion on which type is most promising to be related to effective energy conservation.

Within each type of energy literacy, studies will be reviewed that have assessed levels of energy literacy and the cognitive and social processes that influence this level of energy literacy. Furthermore, the individual differences in relation to energy literacy will be explored to assess what factors can account for individual differences in energy literacy for each type. Next, where available, literature will be discussed that has explored the relation between the specific type of energy literacy and energy saving behaviour. Finally, literature that has explored ways to change each type of energy literacy will be discussed when existing.

The following sections will only review literature on knowledge about energy consumption – which may or may not include knowledge about climate change – but studies that have solely explored people's understanding of climate change (e.g. work on *carbon capability* that reflects understandings of carbon emissions rather than energy use, Whitmarsh, Seyfang & O'Neill 2011), was not within the scope of this review because this understanding does not refer to understandings specifically related to energy use. Moreover, this chapter will not review literature on general energy perceptions as these do not include an evaluation of the accuracy of the perceptions and therefore does not constitute energy literacy. Furthermore, this review will only focus on the energy consumption understanding of an individual in the domestic context. Although research on energy literacy outside of this scope exists, for example in the business sector (e.g. Coles, Dinan, & Warren, 2014) or on a societal level (e.g. Sovacool, 2011), the meaning and implications of energy literacy in these contexts may be profoundly different from the individual domestic context and therefore will not be reviewed here.

5.2 Mental models of home heat control

A mental model is a cognitive representation in which an individual's beliefs of the external reality is conveyed (Morgan, 2014). The way people interpret the operation of their home heat control is an important component of energy literacy as it is likely to vastly affect the interactions with the control. Because heating is a major element of overall domestic energy consumption, heating control has a major impact on energy savings. Furthermore, temperature controllers have been found to be used insufficient, inadequate and are poorly understood (Vastamäki, Sinkkonen, & Leinonen, 2005).

The research on this type of energy literacy repeatedly shows that people's mental models of home heat are poor representations of the true, physical processes at work. Earlier work on perception of the workings of the heating system uncovered that people used one of just two theories to explain the workings of the heating system at their homes (Kempton, 1986). First, the incorrect *Valve Theory* implies that people tend to believe that the thermostat controls the amount of heat the boiler or central furnace generates. Having reviewed previous literature on the adherence of this theory, the authors estimated that 25-50% of the population adhered to an incorrect Valve Theory. In fact, the thermostat controls the length of time the furnace is switched on for — based on the room temperature — while producing a constant flow of heat, also called the *Feedback Theory* (Kempton, 1986). These perceptions influence thermostat interaction because individuals subscribing to the Valve Theory erroneously believe that they need to adjust the setting of the thermostat to regulate the temperature.

Relatedly, people have also been found to assume that a room will heat up quicker when the valve is set to a higher setting (IPSOS, 2014; McGeevor, 1982). That is, people tend to be unaware that turning up the thermostat to a higher setting does not increase the speed with which a space is heated up. It is likely that this is a result of adherence to the Valve Theory, as this theory implies that one can control the amount of heat that flows through the radiator with the thermostat. Furthermore, people have been found to incorrectly believe that leaving the heating on a low temperature constantly, rather than only switching on heating when required, would reduce energy bills (IPSOS, 2014). This misconception is also congruent with the valve theory as it implies that people assume that the thermostat needs to 'work harder' if it is heating a colder room. These findings therefore highlight that people still believe in the Valve Theory in relation to home temperature control.

More recent research has proposed two additional mental models that relate to heating: the *Timer Theory* (Norman, 2002) and the *Switch Theory* (Peffer, Pritoni, Meier, Aragon, & Perry, 2011). The Timer Theory suggests that the thermostat solely functions as a timer, meaning that it simply controls how long the heating system is on for, but does not regulate the temperature in any way (Norman, 2002). Users who subscribe to the Switch Theory use the thermostat only in a switching on-or-off manner, without a timer, and assume that the thermostat does not regulate the temperature (Peffer et al., 2011). Anybody who holds one of these theories about the way a thermostat works is implying that they the user, not the thermostat, is responsible for the maintenance of the optimal temperature in their home.

Unfortunately, whilst these two studies have shown such misconceptions exist, neither tested their prevalence among households or whether individuals can believe in a combination of these theories.

However, a recent qualitative study exploring the mental models of home heat control confirmed that the Valve Theory, Switch Theory, Feedback Theory and the Timer Theory are all still prevalent in today's society (Revell & Stanton, 2014). Nevertheless, not all the interpretations of the home heat control could be classified into one of the four previously discussed mental models, although it was not clear which beliefs underpinned these interpretations, suggesting even more theories that people employ to understand their home heat control may exist.

To date, no studies have explored individual differences in the adherence to these home heat control theories, nor how these theories develop in people's minds or are socially transmitted. More importantly, no literature has been found investigating how people's mental models of the home heat control can be improved although the adherence to inaccurate mental models can be a substantial barrier for domestic energy conservation.

Overall, what can be concluded from these studies is that people tend to have poor understandings of the home heating system and this results in misconceptions about the best way to operate the device. This is important given the high contribution of heating to overall domestic energy use. However, more research is needed to investigate the development and individual differences in relation to the mental models as this low level of home heating energy literacy seems to be a barrier to optimal energy saving behaviour in relation to heating control.

5.3 Device energy literacy

A type of energy literacy that has received considerably more research attention is device energy literacy: people's awareness of the energy consumption of domestic appliances. Most of the methodology to assess people's perception of this energy consumption bears important limitations. For example, in research by Attari, Dekay, Davidson, Bruine and Bruin, (2010), participants estimated the energy consumption that is typically used in one hour by nine devices and the amount of energy that could be saved by engaging in six energy-saving activities using a reference point of a 100 watt light bulb. Results showed that participants tended to greatly underestimate the energy use of energy appliances and activities that consumed a lot of energy (by a factor of 2.8) whereas the energy consumption and savings of appliances and activities that did not involve a lot of energy were slightly overestimated.

However, this study has been strongly criticised for the use of the reference point (Frederick, Meyer, & Mochon, 2011). Frederick and colleagues (Frederick et al., 2011) tested a variety of alternative reference points and concluded that participants' energy judgement is extremely sensitive to the energy consumption level of the reference point, and may even reverse Atari and colleagues' (Attari, Dekay, Davidson, Bruine, & Bruin, 2010) findings. That is, a high energy consuming device as reference point led to major overestimations of the energy consumption and savings of most devices and activities (Frederick et al., 2011). This finding can be attributed to the anchoring-and-adjustment heuristic (Tversky & Kahneman, 1974), in which individuals use a point of reference as a starting value to make a numerical judgement, but do not deviate enough from this starting value, meaning that estimations are always biased towards the reference point. This heuristic (or mental short-cut, see section 5.3.2) implies that the reference point that was provided (the energy consumption of a light bulb) was used as an 'anchor' on which the participants based their response by adjusting their estimate from this reference point (Chapman & Johnson, 2000). The use of this heuristic is inherent to the (perhaps somewhat contrived) methodology of the study and may therefore not be present in real-life energy judgements.

That said, an exploratory survey study using a different method also suggested low levels of device energy literacy in general populations. It reported that the majority of respondents were not able to correctly identify the three most energy-consuming household devices if switched on for 20 minutes (Sundramoorthy, Liu, Cooper, Linge, & Cooper, 2010). Furthermore, less than 20% of the sample correctly identified two out of three devices. However, it needs to be noted that appliances can consume different levels of energy depending on their age, make or production location and therefore, there is no straightforward 'correct' answer in this task. That is, this study claimed that the hob, oven and grill consume most energy, but many sources may instead place the kettle in the top three – as did many participants in this study.

Contrary to the previous studies, one study did find high levels of device energy literacy in a comparable population. Participants rank-ordered 19 household appliances in terms of their energy consumption in one hour of use and the results indicated that participants' rank-orders correlated very strongly (r_s=.81) with the actual energy use of the household appliances (Baird & Brier, 1981). The opposing conclusions within the literature may be due to the differences in methodology. That is, the rank-order task in this study required participants to compare all 19 devices to each other to judge the relative energy consumption of the various devices. This process thereby does not rely on the comparison of each device with one particular device (Attari, Dekay, Davidson, Bruine, & Bruin, 2010) or on the accuracy of the energy estimations of only three devices (Sundramoorthy et al., 2010) but rather assesses whether the perception of the variation in energy consumption between a considerable number of appliances is accurate.

The studies on device energy literacy discussed so far assessed people's understanding of the energy use of appliances independent of the frequency and duration of use of the device by instructing participants to rate the energy use of all appliances for the same length of time. However, studies that have investigated perceptions of the total energy use of appliances per month or year – thereby requiring participants to also estimate the frequency and length of time the device is typically used for – also found low levels of understanding of the energy use of appliances. For example, people seem to misidentify the appliances that use the most energy per month. In a large national survey in the UK, respondents were asked to list the three devices that contribute the most to their electricity bill (Mansouri et al., 1996). The study relied on mean annual consumption per household from a national-wide UK dataset in which the fridge-freezer, freezer and dishwasher used the most energy per year, yet only 6% of the participants listed the fridge-freezer or freezer in the top three. Although many participants did correctly list the dishwasher, two-third of the participants wrongly listed the washing machine, and one-third listed the cooker. Therefore, participants seemed to only have accurate perceptions on the energy use of dishwashers in this survey, and tended to incorrectly list other short-use appliances and underestimated the energy consumption of long-use appliances such as the fridge and fridge-freezer. This suggests that participants may have discounted the length of time the appliances are commonly used for, and focused on the energy consumption of the appliances itself when judging the total energy consumption.

Furthermore, survey studies have consistently found that people tend to overestimate the energy consumption of devices that are more visible in the household such as lights and entertainment, and underestimate the use of less visible items such as home heating systems (Bodzin, 2012; Davis, 1985; DeWaters & Powers, 2011; Stern & Aronson, 1984). This notion may suggest that people might infer the energy use from the visibility of the appliance, which will be further discussed in section 5.3.2.

Two qualitative studies further underlined insufficient knowledge about the total energy consumption of domestic appliances. In one study, participants were engaged in various activities during a home visit to elicit interaction with, and reflection on, the energy use in their home (e.g. they were prompted with energy-related objects and photos, asked to demonstrate and describe their use of home appliances and logged their energy use after being informed about this) (Pierce & Paulos, 2010). Next, the participants were interviewed about their everyday interactions with energy-consuming devices. Although no further details on the interview or analysis were reported, the authors concluded that participants had little knowledge of the energy consumption of household devices except for heating and air-conditioning (which was attributed to the variability in energy bills across seasons).

Second, in a qualitative study by Chisik (2011), participants were asked to draw five devices that they perceived as the most energy consuming. Devices that were drawn most frequently (television and refrigerator) required low to moderate levels of energy, and therefore participants were suggested to have inaccurate knowledge of the electricity consumption of the devices. Nevertheless, the devices that were drawn may have reflected the salience of the device or the ease with which they were drawn rather than real perceptions about their energy consumption. Indeed, many appliances that were drawn to represent energy in the home in a separate task were also frequently drawn for the most draining home appliances task, suggesting that salience of the device may explain which appliances the participants tended to draw.

In a quantitative study that also investigated perceptions of total energy use of household appliances, participants were generally able to identify which appliances consumed a lot of energy and which consumed little energy per year (Schuitema & Steg, 2005). In this study, participants rated the energy use of 26 appliances in comparison to a Hifi-system on 5-point Likert scales. However, in line with the findings by Attari and collegues (2010), participants tended to use a conservative range of energy consumption, meaning they underestimated the energy use of high consuming appliances and overestimated the use of low energy consuming appliances. As participants estimated the energy consumption using a reference point (the Hifi-system) similar to Attari and collegues (2010), it is likely that this bias can also be attributed to the anchoring-and-adjustment heuristic because the estimates did not depart sufficiently from the reference point.

These studies highlight several methodological issues when it comes to measuring people's understanding of the energy use of their household appliances. First, some studies instructed participants to consider the energy consumption when the appliances are switched on for an equal amount of time, thereby disregarding the frequency and length of time of the use of the appliances. Other studies have assessed whether participants are able to identify appliances that make up the largest proportion of their bill, thereby incorporating the use of the device. Although the latter way of measuring device energy literacy may be more relevant when addressing energy conservation, measuring people's accuracy on this task is more complicated. That is, this way of measuring energy literacy requires participants to be aware of the relative energy use of the appliances as well as how much the device is used – two pieces of information instead of one. Furthermore, the actual extent to which each person uses an appliance is likely to vary greatly across individuals which, in the absence of very detailed home-level monitoring, makes it impossible to assess if a participant is correct about their consumption on a monthly or annual basis. Indeed, in most of these studies, energy literacy is effectively being operationalised as whether people can estimate the national average consumption of each appliance, which is information householders can hardly be expected to know.

Furthermore, this literature review revealed issues surrounding the ‘correct’ rating of the energy use of appliances. The same type of appliance can consume different levels of energy depending on its age, make, etc. This is evident in the finding that common household appliances such as freezers have been given energy labels ranging from E (low efficiency) up to A+ (high efficiency) (Palmer et al., 2013). As such, the energy consumption of a household appliance not just differs across household appliances, but also within types of household appliances. This further complicates the assessment of energy literacy and may even explain the findings of studies that suggest that people have low levels of energy literacy.

Overall, then, studies on device energy literacy do not provide a clear picture of the level of people’s understanding of the energy use of appliances, in large part due to conceptual and methodological issues. Furthermore, contradictory findings have been reported for both estimates of energy use for a fixed time-use and estimates for total energy use over a year or month. Hence, it remains unclear if people have a good understanding of the energy use of their appliances or not, and the extent to which this differs across individuals. Such variation might even explain the inconclusive results from the studies reported above.

5.3.1 Individual differences in device energy literacy

Device energy literacy could be expected to be higher among people with stronger environmental attitudes because they are likely to be more motivated to engage in energy conservation. However, this has not consistently been confirmed in previous research. The study by Attari and colleagues (2010) found that participants with stronger environmental concern (as measured with the New Ecological Paradigm; Dunlap, Liere, Mertig, & Jones, 2000) were more accurate at estimating energy consumption of household appliances as well as the energy savings associated with conservation activities. However, Schuitema and Steg (2005) found that environmental attitudes measured with the same scale did not predict energy perceptions. It is likely that the latter study did not find a relation between attitudes and energy perception because it did not take into account the accuracy of the perceptions and only tested the effect of attitudes on the perceived energy consumption. If the accuracy of the energy estimate — rather than the estimate itself — was analysed, the authors may have found that the degree with which people tended to over- and underestimate the energy use was related to their environmental values. As such, patterns may have been overlooked that indicate that participants with stronger environmental attitudes were better at estimating the energy use compared to participants with weaker environmental attitudes.

Attari and colleagues (2010) also found that participants who scored higher on a numeracy test (which required participants to solve simple mathematical problems) were better at estimating the energy consumption of the appliances. Nevertheless, participants' education could not significantly predict levels of energy literacy in the same study. Furthermore, no effect of income on the accuracy of energy estimations was found by Attari and colleagues, although Schuitema and Steg (2005) did find that energy perceptions of a boiler were different between participants with low and high incomes. However, no differences in energy perceptions were found across the income groups for the other 25 devices included in the study. Considering that the p-value was not extremely small ($p<.05$) and significance levels were not corrected for the large number of tests that were done (one analysis was run for each device), this finding is unlikely to be an indicator of a robust effect of income on energy perceptions – which was acknowledged by the authors.

In sum, people with stronger environmental attitudes and higher numeracy skills seem to have more accurate perceptions of the energy consumption of household appliances. Education and income have not been found to affect this type of energy literacy although these findings are based on only two studies and therefore more research on the individual differences of device energy literacy is needed.

5.3.2 Factors influencing device energy literacy

The finding that people with more positive environmental attitudes tend to be better at estimating the energy use of household appliances may reflect stronger motivations to save energy and therefore to educate oneself about this subject. However, even very motivated householders are unlikely to be aware of the exact energy use of all appliances and therefore estimate the energy use of the appliances using (one or more) judgement strategies. The next sections will therefore review literature that has explored methods that people employ in this decision making process.

When people are asked a difficult question, they may respond by answering a simpler question, a process called attribute substitution (Kahneman & Frederick, 2001). That is, when the target attribute is not readily accessible, a heuristic attribute that is more salient and semantically or associatively related, is used instead to infer the target attribute (Kahneman, 2003). However, when the heuristic attribute is not an adequate indicator of the target attribute, systematic biases are inevitable. For example, a weighting bias may occur in which individuals ascribe too much weight to the heuristic attribute and disregard other aspects of the objects, which may have compensated for the bias introduced by the focus on the heuristic attribute (Kahneman & Frederick, 2001). Similarly, when people are asked to estimate the energy use of household appliances (the target attribute) people engage in attribute substitution meaning they infer the energy use of the household appliance by focusing on a different attribute of the device.

Three types of heuristics have been investigated in relation to energy judgements: a size heuristic, a usage pattern heuristic and a visibility heuristic. The first study that revealed the use of heuristics in the energy judgement process was the above mentioned study by Baird and Brier (1981) in which participants rank-ordered household appliances in terms of energy use. As discussed in section 5.3, results showed that participants' rank-orders were strongly correlated with the correct rank order (r_s=.81), indicating high levels of energy literacy. Participants also rank-ordered the appliances in terms of size (the order of the tasks was counterbalanced) and a remarkably strong correlation (r_s=.91) was found between the perceived energy consumption and the perceived size of the appliances, indicating that participants used the size of the objects as an indicator of their energy consumption. Moreover, the correlation between actual energy consumption and volume was also strong (r_s=.75), suggesting that the use of this heuristic may benefit the accuracy of energy estimations. However, the use of the heuristic did result in an underestimation of the energy use of small appliances (e.g. a kettle) and overestimation of the energy use of larger appliances (e.g. a washing machine), which explains why the correlation between perceived size and true energy consumption was smaller compared to the correlation between perceived size and perceived energy consumption. Furthermore, when participants did not have any restrictions in their sorting procedure (before they were asked to rank-order the appliances by energy use or size), participants tended to sort the appliances on function and size, which signals the salience of the size attribute of the appliance.

As relatively small devices can now perform a wide variety of complex tasks — unlike the technology in the eighties — one could expect that this size heuristic would not be as prevalent in today's society. However, more recent studies have confirmed that this heuristic still dominates energy judgement tasks. First, in the qualitative study by Chisik (2011), in which participants drew energy draining devices, participants tended to draw large appliances (television, fridge-freezer, washing machine) and were found to often refer to the size of the appliance while drawing. Participants also mentioned the duration and frequency of use when they chose which appliances they were going to draw for this task, suggesting another heuristic rule in which individuals consider the usage pattern of the device when judging its energy use. This heuristic may seem valid when estimating the total energy consumption of an appliance per month or year, yet it may result in biased estimates for appliances that are generally switched on for a long period of time, but do not use much energy per time-unit (e.g. television, fridge-freezer). Indeed, the use of this heuristic may explain the misperceptions of the energy use in the aforementioned study by Mansouri and colleagues in which participants may have discounted the length of time the appliances tend to be used for (Mansouri et al., 1996).

In the study by Schuitema and Steg (2005), participants rated household appliances in terms of energy use in kWh per year, visibility, ownership, status, necessity and size. Participants were expected to only use few characteristics of the device to estimate the energy use of the household device based on the Categorization by Elimination Model (Berretty, Todd, & Martignon, 1999). The model assumes that only few cues of the object are used to create categories and classify the objects into the categories, to make the categorisation process as efficient as possible. After the categorisation process, generalisations can be made about the objects that are classified in the same category. For example, if the size of a device is used for classification, devices can be classified (or ordered) according to their sizes and a simple rule may be applied to the different categories to quickly judge the energy use of the devices.

Similar to the findings by Baird and Brier (1981) perceived energy use of the devices in the study by Schuitema and Steg was strongly, and positively, correlated with perceived size of the devices (r=.67). Subsequent analysis showed that the ratings of the size could account for 46.7% of variance in the perception of the energy use, signifying that participants strongly relied on this size heuristic in the energy judgements. The perceived energy use was also positively, although moderately, correlated with visibility (r =.38). This is consistent with the finding that people tend to overestimate the energy use of visible systems and underestimate the consumption of invisible systems (Bodzin, 2012; Davis, 1985; DeWaters & Powers, 2011; Stern & Aronson, 1984). However, separate regression analyses for each participant revealed that perceived visibility only explained 3.5% of the variance in the energy ratings on average and the direction of the relation between visibility and energy differed across participants. This means that some participants tended to associate visibility with high levels of energy use whilst others tended to associate visibility of the device with low levels of energy use. However, without correcting for chance capitalisation that is likely to occur when running separate analyses for each participant, it is impossible to conclude that visibility is a commonly used indicator of energy use of a household appliance. The other measures were not, or only slightly, found to correlate with perceived energy use. The authors therefore conclude that people indeed only use few heuristics to estimate energy use, as predicted by the Categorisation by Elimination Model. Nevertheless, only few characteristics of devices were measured in this study whereas many more could have been related to energy ratings, making their hypothesis unfalsifiable. The study would have benefited from measuring the perceptions of a wider range of characteristics to truly assess if people only apply few heuristics to judge the energy use of household appliances.

Taking these three studies that have investigated energy judgement heuristics, all three have found participants to use the size heuristics in which people tend to use the size of an appliance as an indicator of its energy consumption (Baird & Brier, 1981; Chisik, 2011; Schuitema & Steg, 2005). Furthermore, people may be using a usage pattern heuristic as participants referred to the frequency and duration of the appliances when judging the energy use (Chisik, 2011). Finally, a visibility heuristic may be employed in the energy judgement although no strong support was found for the use of this heuristic (Schuitema & Steg, 2005). This review clearly demonstrates the need for more research in this field as only the use of one heuristic has consistently been demonstrated. To date, research has found no evidence that people use the ownership, status or necessity of the appliance as an indicator of its energy use. Nonetheless, appliances have many more characteristics and it is likely that individuals use other characteristics of domestic appliances when judging their energy consumption.

5.3.2.1 Heuristics

The previous sections have discussed which heuristics may be used in an energy judgement. Because heuristics will become a focal part of the remainder of this thesis, the following sections will have a closer look at the concept of heuristics, how they are used and people's awareness of the use of heuristics.

Three conditions for the use of heuristics have been proposed: the judgement-relevant heuristics have to be available, i.e. learned and stored in memory, the heuristics need to be accessible (and therefore easily retrieved from memory) and the heuristic needs to be applicable to the respective judgement task demands (Chaiken & Trope, 1999). These conditions do not specify the way that heuristics are used, meaning whether they are used deliberately or without conscious awareness. When the term was first introduced, heuristics were defined as: "*a strategy — whether deliberate or not — that relies on a natural assessment to produce estimation or a prediction. One of the manifestations of a heuristic is the relative neglect of other considerations.*" (Tversky & Kahneman, 1983, p. 294). This definition explicitly states that heuristics can be used both without conscious effort as well as deliberately, which seems to contradict other definitions of heuristics that emphasise the little cognitive resources that are required for the use of heuristics (e.g. "*Heuristic represent simple decision procedures requiring little information processing",* O'Keefe, 1990, p. 106).

The deliberateness with which heuristics are used have been addressed in dual processing theories, such as the Elaboration-Likelihood Model (Petty, Cacioppo & Goldman, 1981) and the Heuristic-Systematic Model (Chaiken, 1980). These theories assume two cognitive operating systems that have been relabelled as *system 1* to reflect automatic, unconscious processing that is cognitively undemanding, and *system 2* reflecting controlled, conscious processing that requires more cognitive effort (Stanovich & West, 2000). Furthermore, the authors suggest that heuristic processing occurs in system 1, in line with the previous literature on dual-processing theories (Chaiken & Trope, 1999). However, Kahneman and Frederick (2001) have argued that heuristics can be used in both system 1 as well as system 2. Specifically, they propose that cognitive processes can move from system 2 to system 1 when proficiency and skills are developed, but the processes can also move from system 1 to system 2 when the heuristics are adopted to be used deliberately. Indeed, system 2 can override system 1 when enough attention is devoted to the task and the individual has the cognitive ability (Stanovich & West, 2000). Therefore, some heuristics may also be used consciously when an individual either chooses to use a heuristic as a particular strategy or the use of the heuristic is initiated unconsciously, but adopted as a deliberate strategy to infer the unknown target attribute (Kahneman & Frederick, 2001).

Despite the abundance of dual-processing theories that speculate about the way the heuristics are used (Chaiken & Trope, 1999), little research has directly tested whether heuristics are used unconcisouly or consiously, or both. However, studies have shown that the use of heuristics can be elicited by cues that participants are unaware of, therefore suggesting that heuristical processes may be initiated without conciousness (e.g. Ferreira, Garcia-Marques, Sherman, & Sherman, 2006; Gabrielcik & Fazio, 1984). Nevertheless, some heurisitics have been suggested to be used conciously because of their plausibility. An example of such a heuristic is the recognition heuristic, in which people perceive objects that are more easily recongised to have a higher value relevant to the target attribute (Goldstein & Gigerenzer, 1999). Although people’s awareness of the use of this heursitic has not been tested, the authors describe the heuristic as a delibrately used heuristic because it is ecologically rational, and therefore an adaptive strategy to make accurate inferences when limited information is available (Gigerenzer & Goldstein, 1996).

More importantly, it remains unclear in which ‘system’ the energy judgement heuristics are used to estimate the energy consumption of appliances. The studies that have identified energy judgement heuristics have adopted the term heuristics, but failed to address the way that these heuristics were employed or participants’ awareness of the heuristics. The two quantitative studies that explored the use of heuristics in energy judgements (Baird & Brier, 1981; Schuitema & Steg, 2005) did not investigate or observe the use of the heuristics and therefore it remains unclear if participants used these heuristics in a deliberate or automatic way. However, in the study by Chisik (2011), participants were reported to refer to the size of the appliances when drawing appliances that they perceived to be energy draining, therefore suggesting that this heuristic was used deliberately and participants may therefore have been aware of the use of the heuristic.

It is likely that these heuristics can be used both in system 1 (unconsciously) and in system 2 (consciously) considering the straight-forward relation between the heuristic attribute and the target attribute, which is not the case for most well-known heuristics. For example, the availability heuristic involves the inference of the probability of events by the ease with which examples of the event come to mind (Tversky & Kahneman, 1973). The use of such heuristics require the inference of the target attribute from cognitive processes such as ease of retrieval from memory. The size and usage pattern heuristics, however, does not require such introspection as it involves the application of a heuristic attribute that may be easily available or estimated. Therefore, the use of energy judgement heuristics may be more straightforward and lend itself for a deliberate application. If these energy judgement heuristics are indeed used in a conscious way, it is likely that people are aware of the use of these energy judgement heuristics although this has not been addressed in previous research.

The studies that will follow in the next chapters will therefore address the awareness of the use of the heuristics. Both deliberately and unintentionally used strategies to judge the energy consumption of household appliances will be referred to as 'heuristics' because it remains unclear how the strategies are used and the term has been used for both automatic and deliberate use of judgement-strategies. Therefore, this thesis will use the following definition: *an energy judgement heuristic is a cognitive strategy, that may be used deliberately or not, in which energy consumption is inferred from a heuristic attribute to produce an estimate of energy consumption.*

In short, although dual-processing theories suggest that heuristics are not used deliberately but without cognitive effort and awareness, various scholars in the field of heuristics argue that some may be employed deliberately. No research has investigated whether energy judgement heuristics are used in a deliberate or automatic fashion, or whether people are aware of their use of these heuristics, leaving a clear gap in the literature.

5.3.3 Improving device energy literacy

The literature above demonstrates that the use of these heuristics can result in systematic biases in energy estimations of domestic appliances. Therefore, one would expect that attempts to improve this energy literacy have involved addressing the use of these heuristics. However, none of the literature that has investigated how to improve people's understanding of the energy consumption of household appliances has addressed the use of heuristics. As such, no study to date has tested the changeability of energy judgement heuristics despite the literature demonstrating biased energy judgements as a result of their use.

Instead, most of the research looking to improve device energy literacy has focused on residential energy feedback to increase the 'visibility' of the energy use of household appliances (for a review of the effectiveness of energy feedback see, Darby, 2006). These feedback devices have been found to be successful in inducing energy conservation among householders (Abrahamse, Steg, Vlek, & Rothengatter, 2005) although this may depend on householder's engagement and enthusiasm for the monitors (Murtagh, Gatersleben, & Uzzell, 2014). The impact of the feedback on energy conservation has been suggested to be due to an increased understanding of the energy use of household appliances (e.g. Darby, 2008). However, it needs to be noted that most of these energy feedback devices inform the householder about the energy consumption of the entire household rather than individual household appliances, meaning that the improved device energy literacy may not necessarily explain the reduction in energy consumption. That is, the positive effect of the feedback on energy consumption may also be a result of the feedback nudging householders to save energy, as the presence of the device may act as a prompt to save energy. Research that has systematically tested if device energy literacy mediates the effect of energy feedback on energy conservation is lacking, although qualitative research suggests that householders with energy monitors become more energy literate (Schwartz et al., 2013).

Whereas feedback information on energy use through electronic feedback systems is considered contingent information, because the information is delivered after the behaviour is performed (Dennis, Soderstrom, Koncinski, & Cavanaugh, 1990), a number of studies have also explored the effect of providing householders with antecedent information, which is presented before the behaviour takes place. For example, a study that informed a student-housing complex about the energy use of household appliances and energy saving tips through posters, found an initial reduction of 30% in their energy use, but this percentage dropped to 9% in the subsequent week (Hayes & Cone, 1977). These findings need to be interpreted carefully as no control group was included in the study and therefore the effect of the intervention could not be properly tested. Furthermore, the knowledge of the energy consumption of the household appliances was not measured before and after the intervention and therefore the energy conservation cannot be reliably attributed to the information provision.

Although the previous studies suggest that energy feedback and information can induce energy conservation, contradicting findings have been reported in a study that included both types of interventions (Kurz, Donaghue, & Walker, 2005). Three types of interventions were included in this study: information on the energy (and water) use of household appliances and how to reduce their use, labels including the same but device specific information that were to be installed in the home, and feedback sheets that informed households about their energy use in relation to households similar in size that also participated in the study. Conditions included a control group and every possible combination of the interventions, resulting in 8 conditions (e.g. information, information + labels, feedback + labels etc.). The results showed that none of the interventions were successful in inducing energy consumption reductions (whereas the labels were successful in inducing water conservation). Although the interventions relied on the assumption that information on energy consumption would induce energy conservation, energy literacy was not assessed in this study. Hence, it remains unclear whether the interventions were not successful because device energy literacy was not improved through the interventions or because the improved energy literacy did not translate into energy saving behaviours.

To date, the only study that has tested the relation between device energy literacy and energy conservation behaviour using quantitative methods is the aforementioned study by Attari and collegues (2010). The authors did not find that self-reported conservation behaviour was related to the accuracy of energy estimations. This may be due to the dichotomous nature of the measure of conservation behaviour, as participants were asked whether they engaged in a number of energy saving behaviours, which may not have captured enough variation across participants. The link between device energy literacy and energy conservation has also been explored in interviews by Pierce and Paulos (2010), in which participants were presented with the financial costs (and thereby also the relative energy use) of household appliances. Participants said they were not affected by the cost information and reported not changing their interactions with the appliances. However, both of these studies assume that participants are aware of the antecedents of their conservation behaviour and are willing and able to report these accurately. Considering that energy behaviours are often habitual (see Chapters 2-4), suggesting that people may not have sufficient awareness of the energy they actually use, and given that perhaps participants may not want to appear frugal by admitting that they changed their behaviour for small financial gains, studies that measure actual energy saving behaviours are needed to further investigate how device energy literacy can be enhanced and impact energy use as self-report measures are unlikely to be reliable.

Taking all the literature on device energy literacy together, it is evident that this type of energy literacy needs more research attention. The accuracy of people's estimations of household appliances' energy use remains unclear and not much literature has explored the individual differences in regards to this energy literacy. Heuristics have been found to play an important role in the energy judgement process, yet only three types of energy judgement heuristics have been investigated in previous research whereas many more heuristics may be used. Energy feedback devices might induce energy conservation behaviour by increasing householders' knowledge of the energy use of their appliances but this has not directly been tested and more research on device energy literacy is needed because of its potential to empower householders to improve their home energy conservation.

5.4 Energy saving activities literacy

A different operationalisation of energy literacy focusses on people's perception of household energy saving activities. With this type of energy literacy, energy literate residents are able to make informed decisions about energy saving behaviour. They will know what type of energy curtailment behaviour will result in the highest energy saving output and can therefore save energy in an efficient manner. Studies that have explored the perception on energy saving activities show that individuals are not correctly informed about the energy saving impact of these activities. As discussed in Chapter 1, these energy saving activities could consist of efficiency investments (e.g. purchasing energy saving light bulbs), better management (e.g. switching off devices that are not currently being used) and curtailment of comfort (e.g. reducing the temperature on the thermostat) (Kempton, Harris, Keith, & Weihl, 1985).

Low levels of activity energy literacy have been reported in the aforementioned qualitative study by Pierce and Paulos (2010) in which participants have been shown to be unaware of a range of energy saving strategies (e.g. energy saving settings for washing machines, dryers, etc.). This unawareness is further illustrated in a recent poll in which respondents were divided on whether washing dishes by hand would be more cost-effective than using a dishwasher (IPSOS, 2014). Furthermore, several studies have demonstrated that people are not only unaware of a range of curtailment behaviours, they are also not familiar with the relative impact of the different conservation behaviours. A study by Kempton, Harris, Keith and Weihl (1985) showed that when participants were asked to list energy saving strategies, they most frequently reported switching off lights. Furthermore, participants tended to vastly overestimate the energy savings of this curtailment strategy as lighting is only a small part of a household's energy expenditure (DECC, 2015a). The popularity of the energy saving strategy 'switching off the lights' is confirmed by recent statistics that show that household energy consumption for lights have sharply decreased in the UK since 2005 (DECC, 2015a), although this decline may also be (partly) due to the use of more energy efficient lightbulbs.

Furthermore, the study by Kempton and colleagues also found that the impact of other curtailment strategies, such as reducing television use, also tended to be overestimated while the energy savings from efficiency strategies (e.g. purchasing efficient appliances, caulking) tended to be underestimated (1985). This was also found in the study by Attari and colleagues (2010) in which participants were asked to list the most effective ways of saving energy in the home and only 11.7% reported efficiency strategies whereas 55.2% of participants reported curtailment strategies. As estimations for the activities and appliances were analysed together in this study, the findings reported in section 5.3.2 also apply to perceptions of the activities, meaning that participants tended to vastly underestimate large energy savings and slightly overestimate the energy savings from low energy saving activities. However the same limitations to the methods used in this study apply here, in that these under- and overestimations are plausibly a result of the anchoring-and-adjustment bias inherent to the methods of the study (Frederick et al., 2011).

Various studies have compared the understanding of the energy use across different household domains. Studies in the field of environmental education have found that students tend to overestimate the energy consumption spend on cooking, entertainment and lighting but underestimate the energy used for heating and cooling rooms (Bodzin, 2012; DeWaters & Powers, 2008), which may be due to the visibility of these activities. Another study investigated householders' knowledge of the environmental impact of their personal household compared to other households across different behavioural domains (Gatersleben et al., 2002). The findings show that participants were quite aware about the environmental impact of their personal car use, computer use and holidays compared to other households, but were not good at estimating the environmental impact of their cooking activities compared to other households. Because cooking activities are more likely to involve the use of household appliances, these results seem to support the conclusion of the studies in section 5.3 that people are not aware of the energy use of their home appliances.

5.4.1 Individual differences in activity energy literacy

No studies have yet investigated what individual differences exist in relation to the accuracy of the perceptions of energy saving activities specifically. However, the finding that participants with higher numeracy scores and more positive pro-environmental attitudes were better at estimating the use of appliances, also applied to estimations of the energy use of activities as the data for energy perceptions of devices and activities was analysed together in this study (Attari et al., 2010). Furthermore, the study by Gatersleben and Vlek (1998) in which participants compared the environmental impact of their household activities to other households, reported some interesting differences across participants. First, older participants tended to perceive their household behaviours as less environmental damaging than younger participants. Second, unsurprisingly, the more participants reported to use a certain household item, the more they expected their behaviour to be more harmful than others (e.g. bathing, washing behaviours), whereas ownership of the appliance was unrelated to this perception.

5.4.2 Factors influencing activity energy literacy

As these studies suggest that some people are better at estimating the impact of energy saving activities than others, it is important to investigate what factors influence levels of activity energy literacy. Recent work exploring how people judge the energy consumption of energy-related behaviours found that people are susceptible to the symbolic significance fallacy (Sütterlin & Siegrist, 2014). This heuristic causes people to rely on the attributes that have symbolic significance and disregard other information. This bias became apparent when participants underestimated the energy consumption in a scenario including a hybrid car covering more than twice the distance compared to a scenario with a SUV (Sütterlin & Siegrist, 2014). This misjudgement was attributed to participants focusing too much on the eco-friendly aspect of the car and neglecting other information. This is similar to the process that informs energy judgements of household appliances as discussed in section 5.3.2, because attribute substitution takes place when the heuristic attribute is used to make the energy judgement. Nonetheless, no study has explored the role of attribute substitution in the perception of household energy saving activities. People might consider the amount of effort or financial costs that an energy saving activity requires as an indicator of the impact of the behaviour. This would imply, for example, that the energy savings from easy and impactful behaviour such as filling the kettle with a minimum amount of water would be underestimated.

5.4.3 Improving activity energy literacy

The knowledge structure model proposed by Frick, Kaiser and Wilson (2004) (discussed in Chapter 2) distinguished action-related knowledge and effectiveness knowledge, which correspond to knowledge of the available behavioural actions to mitigate these environmental problems and the knowledge of the effectiveness of these actions, and therefore both constitute activity energy literacy here. These types of energy literacy were found to directly predict conservation behaviour (Frick et al., 2004). This suggests that the awareness of the impact of energy saving activities affects energy conservation and hence many efforts have been made to increase people's awareness of the existence and impact of energy saving efforts using a variety of methods.

For example, in a study by Winett and colleagues (Winett, Leckliter, Chinn, Stahl, & Love, 1985), a television programme was tailored to middle-class home owners to inform them about reasons and ways to conserve energy in their home through modelling. Participants that had watched the programme were more knowledgeable about energy use in the home (awareness of impact of energy saving actions, as well as energy requirements of cooling and heating the home). However, the study did not assess the impact of the improved levels of energy literacy on energy consumption.

Another way in which this type of energy literacy can be enhanced is through energy conservation workshops, which engages communities with energy advice to help them to save energy in their homes. These workshops have been found to increase awareness about ways to save energy in the home and commitment to conserve energy (Geller, 1981). However, the increase in energy-related knowledge was specific to the topics covered in the workshop and did not translate into knowledge about other energy related issues that were outside of the scope of the workshop. Moreover, follow-up home surveys showed that few of the energy-saving strategies had been applied in the participants' homes.

Furthermore, several studies have investigated if providing people with information on energy saving tips increases energy conservation. For example, in one study, participants received either an information pack on the energy consumption of cooking appliances and how energy could be saved in food preparing practices or participants received electronic feedback on the energy use of electric cookers and a third group received both types of information (Wood & Newborough, 2003). Participants that had received the information pack reported to have changed more types of household behaviours to save energy, yet this group achieved the lowest level of energy conservation compared to the other two groups. It is likely that this discrepancy may have been due to the measure of energy conservation that only assessed the variety of behaviours but not the frequency of the behaviours and may therefore not have accurately reflected energy conservation.

Interestingly, in one study, information packages (that motivated participants to save energy and advised them on how to save energy efficiently) were found to be more effective to induce energy conservation among householders compared to energy feedback (Gaskell & Pike, 1983). Furthermore, the more knowledge participants had about energy consumption in the home (including knowledge about insulation, the financial impact of heating and how to use appliances and home heating systems efficiently), the more they reported to engage in energy conservation behaviour and the lower the gas use (but not the electricity use) in their home was found to be. This suggests that the effect of the information packages on energy consumption was mediated by the improved energy literacy. However, this was only found for general knowledge. That is, participants' knowledge on the energy consumption of different appliances, including space and water heating, could not account for variations in reported energy conservation and energy consumption levels. However, it needs to be noted that information packages may have been more effective than energy feedback in this study because of the limited available energy feedback technology at the time of the study.

These studies highlighted some positive effects on the awareness of ways to save energy when householders are provided with energy savings tips trough workshops, information packages or television modelling. Nevertheless, only one study found that these tips increased energy literacy that in turn stimulated energy conservation. No study has used systematic and controlled methods to test if the positive effect of information provision on conservation is mediated by increased levels of energy literacy or whether the information provision solely functions as a prompt that induces energy saving behaviour. The mixed findings in terms of activity energy literacy on energy conservation in these studies show that more research is needed to investigate this relation. Furthermore, no studies have addressed ways to enhance the understanding of the relative impact of different types of energy saving strategies.

Importantly for the work that will be reported in this thesis, the research on activity energy literacy revealed biases in estimating the impact of energy saving behaviours. That is, people tend to overestimate the impact of efficiency strategies while underestimating the savings of curtailment strategies. Moreover, giving householders energy savings tips seems to increase their knowledge about how to save energy in the home, but its effect on energy conservation remains unclear.

Taking all the research on activity literacy together, it is clear that this type of energy literacy would benefit from more research attention. Because research suggests biases and misunderstandings in perceptions of energy saving activities, it is important that more research explores this type of energy literacy. That is, it is very likely that perceptions of the impact of energy saving activities affects how people choose to save energy in the home and therefore misconceptions can form a serious barrier to optimal household energy saving.

5.5 Economic energy literacy

In the field of economics, energy literacy has been operationalised as people’s numeric ability to make energy efficient (and thus economic) decisions. This is clearly illustrated in the following definition of energy literacy obtained from a study in the field of economics: “*Whether households are able to make a trade-off between long-term savings from energy efficiency investments and the upfront investments that are required to achieve improvements in energy efficiency*” (Brounen, Kok & Quigley, 2013, p. 43). This definition reveals an assumption that people act rationally and make economic decisions in relation to energy savings. The rational and economic definition of the concept results in similarly rational-choice and economic measurements in Brounen et al.'s (2013) study. The measurement of energy literacy consisted of an item assessing awareness of the costs of the householder’s energy bill, an item inquiring whether the participant consumed renewable energy at home and a trade-off choice scenario in which participants had to choose between a higher energy efficiency investment with higher return rates and a cheaper non-energy efficiency investment that results in higher costs in the long term.

The validity of these measures is highly questionable for a number of reasons. First, asking participants whether they know the costs of their energy bill might not yield valid responses as participants may think they are aware of these costs but without checking the amount with their actual bill, there is no way of knowing whether their estimate is accurate or not. Second, households may or may not consume renewable energy for a number of reasons that may be out of their control (e.g. availability in the region, government regulations/available subsidies etc.). Third, the item on the consumption of renewable energy, measures environmental behaviour rather than knowledge, as it asks participants to report on the environmental friendliness of their current energy consumption rather than their understanding of energy consumption. Therefore, this may not reflect the energy literacy of its users. Fourth, the item in which participants made an economical trade-off merely required mental calculations to assess which scenario would result in the lowest total costs. Therefore, this item arguably measured simple numerical ability rather than energy literacy as people did not have to bring energy knowledge to the calculations. Finally, it seems unlikely that householders have all the details to make these calculations, or are motivated enough to do so, when they make energy efficiency investments in real settings, and this operationalisation therefore might lack ecological validity.

Keeping these limitations in mind, a few interesting results were reported in this study (Brounen et al., 2013). First, only 56% of participants reported being aware of the cost of their monthly energy bill. Second, 60% of participants were able to make a successful long-term trade-off in favour of an energy efficiency investment. Furthermore, level of education was the most successful explanatory variable for energy literacy (which combined all three measures) among the sample – which is perhaps not surprising considering the nature of the measurement as previously discussed. Finally, and perhaps most importantly, given the criticisms above, energy literacy was not found to predict energy conservation behaviour as measured by the self-reported tendency to lower the thermostatic settings during the night.

Remarkably, no other research was found that conceptualised energy literacy in a similar way. However, other research in the domain of economics has explored financial decisions in relation to investments in renewable energy (e.g. Masini & Menichetti, 2012) or market barriers to energy-efficiency investments (e.g. Sutherland, 1991). However, none of this research focused on individual differences in the ability to make financial trade-off decisions in relation to energy efficiency investments.

Furthermore, although a vast amount of literature in the field of economics has investigated how energy consumption changes in response to energy price changes (for a review see Espey & Espey, 2004), no research has investigated if price changes also influence economic energy literacy, or other factors that could affect this type of energy literacy. Moreover, this field has investigated cognitive biases that may be relevant to energy perceptions, such as temporal discounting, which is the tendency for people to discount the value of future rewards (Doyle, 2013) and myopic loss aversion, which is the tendency to be more sensitive to losses than gains resulting in loss aversion (Benartzi, & Thaler, 1993). These cognitive biases are likely to affect energy perceptions as the benefits of energy conservation (financial or environmental) are distant in time and therefore these benefits may be discounted.

As differences in education could account for differences in energy literacy (Brounen et al., 2013), it is likely that this economic energy literacy can be improved through education – although whether this is a useful conceptualisation of energy literacy that translates into energy-saving behaviour is still open to question.

5.6 Scientific energy literacy

The final type of energy literacy that will be reviewed in this chapter is the scientific operationalisation of energy literacy. Research on this type of energy literacy has primarily been conducted in the field of (environmental) education. In some of these studies, energy literacy has been operationalised in a way that also includes other aspects of energy — besides solely scientific energy literacy — such as attitudes towards energy conservation or energy saving behaviour itself. In the following section, the different levels of inclusiveness of the definitions will be discussed and literature on these types of energy literacy will be reviewed.

Research that has investigated the scientific understanding of energy concepts has consistently concluded that children at primary and secondary school have low levels of energy literacy, whether this literacy focuses on a scientific understanding of energy use, energy production and supply, renewable energy, or the understanding of the environmental and societal impact of energy production and consumption (Barrow & Morrisey, 1989; Bodzin, Fu, Peffer, & Kulo, 2013; Bodzin, 2012; Boylan, 2008; Cotton, Miller, Winter, Bailey, & Sterling, 2015; Davis, 1985; DeWaters & Powers, 2011; DeWaters & Powers, 2008; DeWaters et al., 2013; Holden & Barrow, 1984; Lawrenz, 1983; Lay, Khoo, Treagust, & Chandrasegaran, 2013; Solomon, 1985; The National Environmental Education & Training Foundation, 2002). Although research that reported acceptable levels of scientific understanding of energy consumption exists, these studies are the exception and tend to include samples of higher educated students (e.g. Cotton, Miller, Winter, Bailey, & Sterling, 2015).

Research that has also included attitudes towards conservation and renewable energy in their operationalisation of energy literacy concluded that children's positive attitudes towards energy conservation exceed their scientific understanding of energy issues. (Ayers, 1976; Zyadin, Puhakka, Ahponen, Cronberg, & Pelkonen, 2012). In other words, their positive appraisal of energy conservation exceeds their knowledge of how to do so.

In the last few years, energy literacy has become a more broad term as more aspects of energy literacy have been included within the environmental education domain. An energy literacy framework has been proposed for energy education, drawing on existing literature on energy literacy and with the assistance of a panel of specialist in curriculum development, science education and environmental education (Chen, Huang, & Liu, 2013). Energy literacy was suggested to include four dimensions: energy concepts, reasoning on energy issues, low-carbon lifestyle and civic responsibility for a sustainable society of which the latter two were deemed the most important by the experts (Chen et al., 2013), even though these do not reflect knowledge but rather (feelings of responsibility to engage in) environmental behaviours themselves.

In line with this development, an energy literacy questionnaire has been developed by DeWaters and Powers (2013) that has further raised the profile of energy literacy in the domain of environmental education. The energy literacy questionnaire — that is predominantly used in the field of educational to assess energy literacy at this time — comprises of a cognitive component (knowledge, cognitive skills), an affective component (values, attitudes, personal responsibility) and a behavioural component (intentions, involvement and action) (DeWaters & Powers, 2013; DeWaters, Qaqish, Graham, & Powers, 2013). Hence, they have conceptualised an energy literature person as someone who is not only knowledgeable about scientific concepts in relation to energy (e.g. sources of energy), but also feels positive towards saving energy, feels responsible to conserve energy, knows how to save energy in the home environment and has intentions and actions to save energy.

A closer inspection of the items in the attitudes and behaviour sections of the questionnaire reveals that the questionnaire spans a very wide range of psychological constructs in relation to energy use. These include: intention ("*I am willing to buy fewer things in order to save energy*"), various environmental behaviour that do not relate to energy use ("*I try to save water*"), perceived behavioural control ("*I believe that I can contribute to solving the energy problems by making appropriate energy-related choices and actions*"), motivations to save energy ("*I don't need to worry about turning lights and computers off in the classroom, because the school pays for the electricity*"), social norms ("*My family turns the heat down at night to save energy*"), awareness of consequences ("*The way I personally use energy does not really make a difference to the energy problems that face our nation*") and awareness of need ("*Saving energy is important*"). Hence, this questionnaire covers most of the psychological constructs that have been found to relate to environmental behaviour or energy use in particular. In fact, these are all the variables that are included in the CADM (discussed in Chapters 2-4) except for the habits and objective control variable. This questionnaire therefore measures a very wide range of individual differences in relation to energy saving, and does not separate energy literacy from these related constructs. By including items that do not indicate energy literacy, this scale may lack validity as scores on this scale do not just reflect knowledge about energy conservation but motivational factors to save energy as well.

That said, the main focus in this questionnaire is still participants' understanding of the scientific concepts underpinning energy consumption, spanning 50 of 85 items. The majority of these items assessed knowledge about sources of energy. Only four items in the knowledge section assess what has been labelled in this review as device or activity energy literacy (e.g. "*Which of the following items uses the MOST ELECTRICITY in the average American home in one year*?"). Therefore, using this questionnaire, an energy literature person could be someone with great scientific knowledge on energy consumption and strong feelings of responsibility to conserve energy but lacking practical knowledge on how to translate these intentions into efficient energy saving behaviour.

An earlier version of this questionnaire was used to measure energy literacy among middle and high school students in the US and results showed that students scored lowest on energy related knowledge that comprised knowledge of basic energy concepts, energy (re)sources and environmental/societal impacts of energy use (DeWaters & Powers, 2008). However, this questionnaire did not yet include items measuring knowledge about energy consumption in the home and ways to save energy. Furthermore, the latest version of the questionnaire (DeWaters et al., 2013) was validated in an Asian population among Malaysian secondary school children and results revealed low levels of energy literacy among the pupils (Lay et al., 2013). Participants again scored low on the cognitive items, particularly on questions related to current events, home energy use and energy conservation. This all suggests that children have low levels of scientific understanding of energy consumption as well as on how to save energy in their homes.

In sum, scientific understanding of energy issues has mostly been studied in school samples, and has consistently been found that this knowledge tends to be poor. More recent research in the domain of environmental education has started including more attitudinal and practical knowledge about energy consumption that enables people to save energy in their homes, but again knowledge tends to be poor. However, the addition of these behavioural items to DeWaters's framework is interesting, as it suggests a growing movement by US researchers away from seeing energy literacy as scientific knowledge and towards seeing it as a multifaceted concept comprising emotions, knowledge and the ability to save energy. Whether such a multifaceted approach usefully sits under the single rubric of 'literacy', however, is another question.

5.6.1 Individual differences in scientific energy literacy

Some demographic factors have been related to knowledge about energy issues. A study measuring environmental knowledge in relation to energy and pollution found that students with higher levels of knowledge tended to have parents with higher incomes, had taken more high school science courses and were more likely to be male (Gambro & Switzky, 1999). Nevertheless, it needs to be noted that environmental knowledge was only measured with seven items and the items in relation to energy tended to focus on sources of energy. Whereas Ayers (1976) did not find any significant gender differences in attitudes towards energy related issues among secondary high school children, Kuhn (1979) found that girls were more favourable in terms of need for energy conservation and governmental regulation but boys had more faith in technology and the development of new energy resources.

The aforementioned study by Lay and collegues (2013) found no significant gender differences in any of the components of energy literacy as tested with DeWaters and Power's energy literacy measure (2013). However, the study did report that students living in rural areas scored lower on affective and behavioural energy literacy but higher on the cognitive component of energy literacy. A possible explanation for these differences in cognitive energy literacy is that education in rural areas tends to be more limited in terms of resources and teaching training facilities. Nevertheless, rural students expressed stronger environmental attitudes and pro-environmental behaviour compared to their urban counterparts. This study therefore showed inconsistent differences in energy literacy between rural and urban students.

Although most of the research on scientific energy literacy has been conducted with school children or youth, adults have been found to similarly have limited knowledge about energy. For example, a national survey in the US found that young adults were unfamiliar with conversion processes, imbalances between supply and demand and reserves, but did have some knowledge on energy conservation in the home and in relation to transportation (Holmes, 1978). A slightly more recent survey among the general population in the US also reported a lack of scientific energy literacy as respondents scored low on an energy knowledge 'quiz' (The National Environmental Education & Training Foundation, 2002). Specifically, respondents were found to score particularly low on items assessing knowledge about the main method of electricity generation, the most effective way to address energy demands, and the energy consumption of the transportation sector (The National Environmental Education & Training Foundation, 2002).

Because a lot of research on scientific energy literacy has incorporated environmental attitudes into their operationalisation of energy literacy, little research has investigated if environmental attitudes can predict the more purely scientific understanding of energy consumption. One study explored participants' attitudes and efficacy to mitigate energy issues in the context of scientific energy literacy (Cotton et al., 2015), and reported good understandings of energy sources, poor understandings of energy consumption and weak perceived behavioural control to mitigate energy related problems through energy conservation. However, these constructs were not statistically related to levels of energy literacy as the results were solely reported in a descriptive manner which prevents any conclusions to be drawn about the relations between them and therefore this relation remains to be investigated.

In short, the research exploring individual differences in relation to scientific energy literacy have revealed some specific sex differences, but no study has demonstrated any firm patterns in terms of individual differences for general scientific energy literacy. More research is therefore needed as it can reveal which students may need more assistance in developing this type of energy literacy.

5.6.2 Improving scientific energy literacy

Although this type of energy literacy is often assessed, especially in schools, no studies have been found that have explored the effect of scientific energy literacy on energy conservation behaviour specifically. This might seem surprising, but the lack of research may be because scientific energy literacy is developed among pupils as part of a more general environmental education curriculum and therefore the specific impact on energy conservation is less of interest in this field. Alternatively, the energy knowledge that is transferred to the students in the curriculum may not be explicitly linked to recommended actions.

It is widely assumed – even despite this lack of evidence – that when people are informed about the problems associated with energy generation and consumption, this will change behaviour. Therefore, strong efforts have been made using various methods to increase this type of energy literacy. Because scientific energy literacy is deeply embedded in the field of environmental education, it will come as no surprise that this energy literacy has most often been addressed through education. School curriculums across the world have been said to be committed to environmental education to foster environmental knowledge, to stimulate positive environmental values and to encourage appropriate actions (UNESCO-UNEP, 1976).

An early review of the energy education literature concluded that well-designed environmental educational interventions can have a positive effect on students' and teachers' attitudes and knowledge in relation to energy concepts (Morrisey & Barrow, 1984). Furthermore, more recent studies confirm that energy education can increase knowledge on scientific energy concepts such as energy conversions, energy resources and renewable sources (e.g. DeWaters & Powers, 2011) even in the long term (Hanson, 1993) especially when the education is more hands-on (Huang, Chou, Yen, & Bai, 2012), or if interactive technology is used (Bodzin, Fu, Peffer, & Kulo, 2013).

However, the effect of energy education on energy saving efficacy and conservation behaviour remains unclear as some studies report increased conservation behaviour (Hanson, 1993), but others fail to prove impact on positive attitudes and efficacy in relation to energy saving and energy conservation behaviour (DeWaters & Powers, 2011b; Dwyer, 2011).

Scientific energy literacy formation in children has been argued to not only be formed by the school curriculum but also by media and through interaction with parents (Aguirre-Bielschowsky, 2013). Parents play a particularly important role in this process, and their influence is transferred to children through modelling, rules and prompts as well as parents' environmental values and attitudes (Aguirre-Bielschowsky, 2013). However, no studies have been found that have explored the role that parents can play in interventions to enhance this type of energy literacy. Considering the important role parents play in the formation of energy literacy, this seems to be a valuable avenue for future research.

The literature reviewed on this type of energy literacy tended to reveal low levels of scientific understanding of energy use, despite positive attitudes towards energy conservation. It remains unclear what type of individual differences can account for differences in scientific energy literacy and this topic would therefore benefit from more research. Although environmental education might improve children's understanding of the adverse consequences of energy generation to the environment, the curriculum may be too abstract and not directly relate to energy saving practices. The lack of focus on daily energy consumption — including energy use of home appliances and ways to save energy — in environmental education programs seems to prohibit the translation of positive attitudes and intentions to save energy that result from the education into effective energy saving behaviour.

5.7 Conclusion

The literature review in this chapter clearly demonstrates the wide variety with which energy literacy has been defined, tested and addressed. One way energy literacy has been conceptualised is the understanding of the home heat system whereas in other research energy literacy was thought to be people's ability to assess the economic benefits of energy efficiency investments. An energy literature person has also been defined as someone who can accurately estimate the energy consumption of their household appliances, still other researchers define energy literacy as the awareness of (the relative impact of) energy saving activities. Finally, within the environmental education domain, energy literacy has been defined in a number of ways, although all of this research expects an energy literate person to have a good scientific understanding of energy consumption.

Critically, however it is defined, nearly all research on the different types of energy literacy concludes that people tend to have low levels of energy literacy. Research that has explored people's mental models of home heat control revealed various mental models that do not correspond with the true operation of home heat control. Many people are not able to make economical trade-offs when it comes to energy efficiency investments. The majority of both the research looking at people's understanding of the energy use of household appliances per time-unit and total energy use per month/year, concludes that people have inaccurate energy perceptions of household devices. Furthermore, studies assessing the perceptions of household energy saving activities showed that people are unaware of a range of energy saving activities and misperceive the relative impact of them. Moreover, the scientific understanding of energy consumption has also been found to be insufficient among different populations.

However, energy literacy levels do seem to differ across individuals. People with higher levels of education have been found to have higher economic and scientific energy literacy, whereas this factor could not predict activity and device energy literacy. The latter types of energy literacy were found to be higher for people with higher numeracy skills and with stronger pro-environmental attitudes. No consistent gender or income differences have been found for any of the types of energy literacy, nor have individual differences in the understanding of the home heat control been studied.

Little research has studied the development of the different types of energy literacy, although several studies have investigated the energy judgement process that feeds into device energy literacy. The energy judgement of appliances has been found to involve a process of attribute substitution in which characteristics of the device, such as size or usage pattern, are taken as an indicator of its energy use. These types of heuristics may also affect activity energy literacy but this remains to be studied. Scientific energy literacy has been found to be influenced by the school curriculum, the media and interaction with parents.

The individual differences in energy literacy for people with different education levels suggest that energy literacy can be improved. Indeed, environmental education has been found to foster positive attitudes towards energy conservation and scientific energy literacy. Different types of interventions – such as television modelling, workshops, and information packages – have also been found effective to enhance people's awareness of the (relative effectiveness of) energy saving actions although the effect of these methods on energy conservation remains understudied. Energy feedback has been found to be successful in inducing energy conservation among householders, but whether this is a result of improved device energy literacy remains unclear. Although the important role of heuristics in energy judgements has been established in previous research, no studies have addressed the use of these heuristics to improve energy literacy. Furthermore, no research has assessed whether economic energy literacy or people's understanding of the home heat control can be increased.

Although the research suggests that energy literacy can be improved and it is likely that knowledge about energy consumption can empower people to save energy in their home, the relation between energy literacy and energy conservation remains understudied. Adherence to incorrect mental models on home heat control are likely to result in inefficient operations of the home heat control and may therefore forms a barrier for energy saving behaviour. Energy feedback has been found to encourage conservation, however, controlled studies that test if the conservation behaviour is due to the improvement in energy literacy or whether energy feedback worked as a prompt for energy conservation is lacking. Activity and device energy literacy have not been found to be related to self-reported energy conservation and the relation between scientific energy literacy and conservation behaviour remains understudied. Therefore, more research is needed that tests the relation between energy literacy and energy consumption. It is likely that such studies will find that improving energy literacy is necessary, but not sufficient to induce energy conservation as more factors influence this behaviour. That is, many driving factors have been found to influence energy conservation in Chapters 2 till 4 and therefore these factors need to be considered together with energy literacy. As proposed in the multiplication model of energy literacy and drivers, proposed in Chapter 1, these driving factors might be the first step towards energy conservation and energy literacy might be a necessary second step. That is, when one is motivated to save energy, knowledge on how best to save energy is crucial to achieve high levels of energy conservation.

The types of energy literacy that seem most promising to induce energy conservation are device energy literacy and activity energy literacy. These types of energy understandings are related to everyday interactions with energy consumption and are therefore most closely related to actual energy use. Hence, these two types of energy literacy will be the focus of the remainder of this thesis. This literature review revealed various gaps and limitations in the existing research on these types of energy literacy. First, findings of the studies that have been conducted on device energy literacy were subject to various methodological limitations. Providing participants with a reference point to estimate the energy consumption has been found to induce an anchoring-and-adjustment bias. Furthermore, estimations of total energy consumption of appliances per month or year requires participants to estimate the energy use per unit of time as well as the length of time and frequency with which the device is used in the general population. This is therefore an extremely complicated task and the result may be more reflective of numeracy skills (as confirmed in previous studies) than the understanding of the relative energy use of household appliances. Even more problematic is the difficulty with which the accuracy of the participants' energy estimates can be determined. That is, to assess the exact use and consumption of each device, energy measuring technology is required which is expensive and participants may find them intrusive.

Therefore, a more controlled way of measuring device energy literacy is assessing people's energy estimations of each device for the same unit of time as this only measures the perceptions of the different levels of energy use of the appliances, without factoring in the interaction with the device. Nonetheless, this way of measuring device energy literacy may be less closely related to energy saving practices as it does not necessarily identify the appliances that have the most potential for energy savings. Furthermore, as mentioned above, this measure does not overcome the issue of variation in energy consumption across the same type of device. That is, the same device can consume different levels of energy depending on their make, country of production and age, which further complicates the evaluation of the accuracy of energy estimates.

The literature on device energy literacy hints at the important role of heuristic in the decision making process, yet only little is known about this process. That is, strong support was only found for the size heuristic, although many more possible heuristics may be employed in this decision making process. As the use of heuristics can have a great impact on the level of energy literacy and thereby people's ability to save energy, this is an extremely important topic and therefore the remainder of this thesis will investigate the use of heuristics in device and activity literacy.

Furthermore, literature has shown that heuristics can be used consciously and unconsciously, yet it remains unclear how these energy judgement heuristics are used and thereby whether people are aware of the use of the energy judgement heuristics. This will therefore also be addressed in the following chapters using a variety of methods. Finally, although the use of these heuristics has been found to result in systematic bias in energy perceptions, none of the studies have investigating whether energy literacy can be improved by addressing the use of these heuristics. That is, no study has explored if the use of these heuristics can be changed, and if this can improve device and activity energy literacy. More importantly, no literature has investigated whether changing the use of these heuristics can enhance energy conservation. These topics will therefore be examined in Chapter 8 of this thesis.

Chapter 6: Exploring Heuristics in Energy Judgements Using Qualitative Methods

Previous research on the use of heuristics in energy judgements has explored a limited number of heuristics and methodological issues limit the generalisability of the findings of such studies. Only two types of heuristics have been identified to be employed in an energy judgement (a size heuristic and a usage pattern heuristic) whereas many more attributes of the appliance could be used to infer its energy consumption. This study was the first in a series of studies that further investigated the use of heuristics in an energy judgement by providing a comprehensive account of energy judgement heuristics. Additionally, the nature of the use of these heuristics was explored and discussed. Focus groups were conducted in which participants performed a joint rank-order task, ranking 23 household appliances by energy consumption. Discussions were recorded and thematic analysis was conducted to identify heuristics that were used in this decision making process. Participants used 28 different energy judgement heuristics during the task. These heuristics were categorised into nine themes (in descending order of the frequency of occurrence): task, knowledge, force, physical features of device, relative standing, temporal patterns, multiple consumption modes, temperature and experience. This study demonstrated that energy judgements are vastly more complex than previously assumed and future directions are proposed.

6.1 Introduction

Chapter 5 has highlighted why it is not only important to investigate what motivates people to save energy, but people's knowledge about how to save energy most efficiently is equally important. That is, it is essential to investigate people's understanding of energy as misconceptions about energy consumption are likely to limit energy conservation practices. Individuals with a good understanding of energy consumption, or high level energy literacy, are able to make informed decisions and know how to save energy efficiently and effectively. Chapter 5 has reviewed the literature on energy literacy and discussed the various types of energy literacy that have been studied. Two types of energy literacy were judged to be most closely related to energy behaviour: device energy literacy and activity energy literacy. This chapter will further explore the antecedents of device energy literacy (see Chapter 8 for an investigation of activity energy literacy).

6.1.1 Device energy literacy

Device energy literacy reflects people's ability to estimate the energy consumption of household devices accurately. As discussed in Chapter 5, this type of energy literacy has been investigated using both quantitative and qualitative methods in previous research. Two quantitative studies have found that people tend to use a conservative range when judging the energy consumption of household appliances; the energy use of high energy consuming devices are underestimated while the energy use of low consuming appliances are overestimated (Attari et al., 2010; Schuitema & Steg, 2005). However, the methodology of such studies, in which participants rated the energy consumption of appliances in comparison to a reference point, has been strongly criticised because of its susceptibility to the anchoring-and-adjustment heuristic (Frederick et al., 2011) and the reliability and validity of these findings are therefore questionable. Another quantitative study used a ranking methodology and found that participants were good at estimating the energy use of appliances as the rank-order of the energy use of the appliances correlated strongly with the 'correct' rank-order (Baird & Brier, 1981).

However, qualitative studies that have explored device energy literacy report that people tend to have insufficient knowledge about the energy consumption of domestic appliances. For example, in a study in which participants were asked to draw energy draining devices, participants tended to draw appliances that did not consume high levels of energy such as a television (e.g. Chisik, 2011). Nevertheless, participants may also have chosen to draw these particular devices because of their salience or the ease with which these appliances could be drawn. Furthermore, the authors of a study in which participants were interviewed about their interactions with household appliances and their energy use also concluded that householders had inaccurate energy perceptions (Pierce & Paulos, 2010). The mixed findings of these studies and their methodological limitations therefore do not provide a consistent account on people's ability to estimate the energy use of domestic appliances and therefore the current study will further explore this device energy literacy.

6.1.2 Heuristics in energy judgement

As discussed in Chapter 5, some of these studies found that participants employed heuristics when judging the energy consumption of household appliances (Baird & Brier, 1981; Chisik, 2011; Schuitema & Steg, 2005). Heuristics are simple rules that are used to reduce the cognitive load of decision making and prevent information overload (Chaiken, 1980). Heuristics are a result of a process of attribute substitution in which people tend to use an alternative attribute to infer the target attribute (Kahneman & Frederick, 2001). The use of these heuristics can result in misestimations of the energy consumption of appliances when the alternative attribute is not a valid indicator of energy consumption.

To date, research has identified two types of heuristics that are employed to judge the energy consumption of household devices. First, participants have been found to use a size heuristic meaning that the size of the device is used as an indicator of its energy consumption (Baird & Brier, 1981; Chisik, 2011; Schuitema & Steg, 2005). With this heuristic, large devices are thought to use more energy in comparison to small devices, which implies that the energy consumption of small devices tends to be underestimated whereas the energy consumption of large devices is overestimated.

Second, people have been found to employ a usage pattern heuristic in which the interaction with the device is considered to determine its energy consumption (Chisik, 2011). With this heuristic, devices that are used frequently or for long periods of time are thought to use a lot of energy whereas devices that are rarely used and for a short amount of time are thought to consume low levels of energy. Therefore, the use of this heuristic implies that devices that are rarely and shortly used tend to be underestimated whilst devices that are used frequently and for a long time will be perceived as using high levels of energy.

Furthermore, the visibility of the appliance has been suggested to be considered when judging the energy use of home appliances systems (Bodzin, 2012; Davis, 1985; DeWaters & Powers, 2011; Stern & Aronson, 1984). However, the only study that has investigated the use of this potential heuristic with experimental methods did not provide sufficient evidence for the use of this heuristic, nor was the heuristic used in a consistent manner (Schuitema & Steg, 2005).

These studies show that only the use of two energy judgement heuristics have been confirmed in previous research. However, appliances have numerous attributes that could potentially be used in the attribute substitution process, in which heuristics are used to infer the energy use of the appliances. As people tend to feel unsure about the energy consumption of home appliances (Pierce & Paulos, 2010), it is likely that people consider other characteristics apart from its size and the interaction with the device when judging its energy use. For example, people may consider the heat that the appliance produces because heat production tends to require high levels of energy, or people may consider the number of tasks that an appliance conducts when judging its energy consumption. Previous research has only investigated few possible heuristics, all which had been hypothesised prior to the study, and therefore little is known about the variety of attributes that are considered in energy judgements. Hence, the current study has further investigated energy judgements to provide a comprehensive account of the different energy judgement heuristics.

As discussed in Chapter 5, models on heuristics tend to suggest that heuristics can only be used in a unconscious and unintentional manner (Chaiken, 1980; Petty, Cacioppo, &

Goldman, 1981; Stanovich & West, 2000), whereas various scholars argue that some heuristics may also be used deliberately (Goldstein & Gigerenzer, 1999; Kahneman & Frederick, 2001). No research has investigated how these energy judgement heuristics are employed, and it therefore remains unknown if people are aware of the use of these energy judgement heuristics. Some heuristics may be used without conscious awareness, whereas others may be employed deliberately and therefore people may be aware of the use of some energy judgement heuristics but not others. This study therefore explored participants' awareness of energy judgement heuristics to investigate the deliberateness with which the heuristics tend to be used.

6.1.3 Research aims

The current study aimed to map the heuristics that are used in energy judgements. Specifically, the objective of this research was to confirm the use of heuristics that have been found in previous research and extend the existing literature by investigating which other heuristics are also used in this process. This study also explored people's awareness of the use of these heuristics to get a sense of the deliberateness with which the energy judgement heuristics tend to be used. Moreover, it explored the accuracy of people's energy judgement and examined people's perceptions of their energy judgement and whether inaccurate energy judgements tend to be attributed to the use of invalid heuristics, which would further highlight the awareness of the use of energy judgement heuristics.

6.2 Method

A qualitative approach was taken to map the energy judgement heuristics, which allowed for any possible heuristic to be uncovered in this study. This is in contrast with previous studies that explored the use of hypothesised heuristics by measuring whether the energy rating of an attribute could be statistically related to the energy judgement (Attari et al., 2010; Baird & Brier, 1981; Schuitema & Steg, 2005). These studies therefore only investigated the use of heuristics that were hypothesised a priori by the researcher, rather than observing the use of any heuristics participants chose to use in their decision making process. The use of qualitative methods therefore facilitated the observation of heuristics that may not have been anticipated as it does not rely on the assumptions of the researcher. This is similar to the study by Chisik (2011), in which participants were free to refer to any attributes of the appliance when drawing the appliances that they perceived to be the most energy draining. However, participants did not directly compare the energy use of different appliances in that study and therefore were unlikely to consider a range of attributes when they chose which appliance to draw for this task. Therefore, different qualitative methods were employed in the current study.

A rank-order task was conducted in a focus group setting which is a group discussion that explores a specific set of issues (Barbour & Kitzinger, 1999). As discussed in Chapter 3, focus groups are characterised by the interaction between the participants that may be generated by stimuli (Barbour & Kitzinger, 1999). Focus groups are ideal when the researcher aims to elicit a wide range of views and to explore under-researched areas as this method is not necessarily based on previous knowledge about the topic (Frith, 2000; Underhill & Olmsted, 2003). Because this study aimed to uncover as many energy judgement heuristics as possible, these aims were likely to be satisfied with a focus group methodology. In contrast to individual interviews, the focus group provides a 'naturalistic' setting in which people can ask questions, challenge and agree or disagree with each other (Braun & Clarke, 2013; Wellings, Branigan, & Mitchell, 2016). This aspect of focus group methodology was ideal for the research aim of this study as it meant that (dis)agreement on energy judgement heuristics, and thereby a range of different types of energy judgement heuristics, were likely to be identified. This method has been demonstrated to be efficacious in a study by Kitzinger (1990), in which participants jointly ranked profiles of different people according to their perceived susceptibility to AIDS in order to investigate people's understanding of AIDS media messages.

To prompt the use of heuristics, this study used a rank-order task similar to the study by Baird and Brier (1981). This task involved the rank-ordering of a number of household appliances by energy consumption and therefore required the direct comparison of the energy use of devices, which was likely to result in the consideration of a variety of attributes of the different devices. The rank-order task does not involve participants using a reference point, which was found to be problematic in Chapter 5. Furthermore, it requires participants to estimate the energy use of all appliances for a fixed amount of time and the energy consumption is expressed relative to other appliances, thereby bypassing the issue with the differences of energy consumption across different makes or ages of the same type of appliance. Furthermore, this task allowed the use of heuristics to occur spontaneously without explicitly prompting participants to use certain heuristics which could make participants aware of the observation of their decision making process and the research objectives.

The rank-order task designed by Baird and Brier (1981) did not involve the observation of the use of heuristics. Instead the use of heuristics was inferred retrospectively by the authors by comparing the rank-order of appliances ranked by energy use with the order of the appliances ranked by size. This method is thereby not only limited by the variety of heuristics that could be inferred but also the validity of the findings is limited as the participants were not observed to use the heuristics.

Therefore, this rank-order task was amended to allow for the observation of the energy judgement process by having participants conduct the rank-order task in collaboration with other participants in a group. This group setting ensured that participants voiced the heuristics that were used to complete the rank-order of the devices, which would not have been possible in an individual setting. As such, the rank-order task functioned to generate discussion about the methods that could be used to estimate the relative energy consumption of the household appliances. The aim of the task was to come to an agreement on the rank-order of the appliances, although participants were invited to express disagreements in the process to uncover a wide number of perspectives and heuristics. Because reaching a consensus is central to focus groups (Braun & Clarke, 2013), this group task fitted in well with this method. The discussions reflected negotiations between participants on strategies to complete the task which included expressions of (dis)agreement, criticism or the validity of proposed strategies, and participants asking other participants to clarify or justify the proposed strategies. However, these social interactions were not the focus of this study because the rank-order task was conducted in a social setting merely to provide access to the heuristics. Therefore, the social processes involved in the use of the heuristics were not investigated specifically, although these factors were taken into consideration in the analysis when they were directly related to the identification of the heuristic (e.g. when participants finished each other sentences or extended each other's statements on the heuristic).

Furthermore, the original rank-order task (Baird & Brier, 1981) was adjusted to avoid possible underestimations of the energy use of items that are commonly used for a short amount of time. That is, participants were instructed to compare the appliances' energy consumption for only one minute of continuous use instead of the one hour time-unit that was used in the original rank-order task.

As this method did not rely on self-report, it uncovered both heuristics that were used deliberately as well as heuristics that were used without awareness of the participants. Therefore, this task was followed-up with questions about the strategies that participants had used to complete the task. These questions facilitated the comparison between participants' perceptions of the use of the heuristics and the researcher's observation of the use of the heuristics. As participants are unlikely to accurately report the use of heuristics that are used unconsciously (Chaiken, 1987; Chaiken, 1980), a discrepancy between the two measures provided a first indication of which heuristics are used consciously and which are used unconsciously.

Similar to the study reported in Chapter 3, care was taken to urge participants to feel free to express deviant views or to disagree with each other and invite quiet participants to contribute to the task to ensure that discussions were not just representative of a few dominant participants (Barbour & Kitzinger, 1999). Furthermore, to keep the participants focussed on the aim of the study, participants were encouraged to focus on the rank-order task as much as possible when they seemed to dwell on unrelated issues (Braun & Clarke, 2013).

6.2.1 Ethical approval

Approval was granted by the University of Bath Department of Psychology ethics committee, reference number 12-156.

6.2.2 Participants

The rank-order task was conducted in the first part of a focus group, while in the second part participants' perceptions of the influences on their energy behaviour were explored for the study reported in Chapter 3, and therefore the same participants took part in both studies. Participants (N = 26, age M = 18.96, SD = 1.11, 57.7 % female,) were first year undergraduates living on campus at the University of Bath who participated in the study in return for course credit or a financial reward. Participants were recruited through online (social media, online fora, noticeboards) and offline (posters) advertising and they were awarded course credit or a financial incentive (£5) for their participation. The advertisement did not mention the focus on environmental behaviour in the study, to avoid sampling bias. The majority of the sample consisted of British participants; five participants originated from other Western countries.

Due to the poor attendance at two of the scheduled focus groups, these were continued on as a thinking out-loud task to mimic the procedure in the other focus groups. These participants were found to report to use more heuristics when they were asked to reflect on their strategies, suggesting that the thinking out loud instructions may have made them more aware of the use of the heuristics. This indicated that the process with which the task was conducted was significantly different and therefore the data for these participants is not reported in this chapter.

6.2.3 Materials

For the rank-order task, 23 common household devices were selected, ensuring a wide range in energy requirements, household tasks and size (e.g. tumble dryer, kettle, electric toothbrush, see Appendix F for the comprehensive list). Each device was labelled on a separate laminated card. Furthermore, a list of the 'correct' rank-order of the devices was constructed with the 23 devices in ascending order of energy consumption with the accompanying Wattage that each device consumes per hour and per minute (see Appendix F). To construct a reliable list, the mean Wattage was taken from various online sources for each appliance (Draft Logic, 2008;

FrequencyCast, 2012; Michael Bluejay Inc., 2012; U.S. Department of Energy, 2012) as the energy use of appliances can differ for the same appliance (see Chapter 5).

6.2.4 Procedure

The task of the focus group relevant for this study lasted between 10 and 25 minutes and started with the rank-order task. The cards were presented to the participants in random order on a table top. The instructions emphasised to jointly determine the order, and therefore participants were expected to reach a consensus about the rank-order of the appliances. They were requested to express any disagreements and justification for ranking the appliances in a certain order and no time limit was imposed. Moreover, participants were instructed to compare the appliances' energy consumption for only one minute of continuous use. After the completion of the task, participants were asked to describe the strategies they had used to rank the appliances (*Could you tell me what kind of strategies you used to determine the position of the appliances in the rank=order?).* Next, they were shown the list of the correct rank-order of the energy requirements of the appliances (see Appendix) and were asked to comment on this list and give potential explanations for any misjudgements (*This is the correct order of energy use of these appliances. What do you think?*). The entire session was recorded using audio recorders and transcribed verbatim with the QRS Nvivo data management program (QSR International Pty Ltd., 2012).

6.2.5 Analysis

The discussions during the rank-order task were analysed with thematic analysis (Braun & Clarke, 2008) to identify heuristics used in the rank-order task. The following sections will elaborate on the justification, epistemology and process of this analysis. The other analyses that addressed the awareness of the heuristics, the accuracy of the rank-order, and the responses to the correct rank-order will be shortly discussed in the respective findings sections in this chapter.

6.2.5.1 Thematic analysis

Thematic analysis is an analysis that facilitates the identification, and communication of patterns within the data (Braun & Clarke, 2006). This is done by coding the data and organising these codes into overarching themes. As this analysis permits the identification of patterns within the dataset, it facilitated the organisation of the participants' discussions into a system of heuristics that determined the rank-ordering of the household devices. This type of analysis has been successfully applied in other studies that have used stimuli to elicit discussion. For example, a study that had children play a game to stimulate discussions, used thematic analysis to investigate their perceptions of their teacher's feelings (Andersen, Evans, & Harvey, 2012).

As the aim of the analysis was to uncover the type of heuristics the participants used during the rank-order task, the analysis aimed to identify a range of heuristics that emerged in this task and not to evaluate whether the heuristics were valid or not. That is, because this study was to identify energy judgement heuristics, more in-depth analyses would not have been appropriate. Discourse analysis, although useful for exploring how the social context constructs people's understandings (Ashworth, 2003), would have been too sensitive, and would have gone beyond the aims of this study. Furthermore, it stands in epistemological opposition to the researcher's stance. As discourse analysis is based in a constructionist epistemological background (Ashworth, 2003), it would have stood in stark contrast to the post-positivist position that the researcher took, and would have been incompatible with the subsequent studies within this thesis. Another potential analytic technique that could have been used is interpretative phenomenological analysis. As this analysis is focussed on the individual sense-making of people (Ashworth, 2003), it would have been inappropriate for use in a focus group setting, where individual experiences are difficult to attain (Ashworth, 2003), and these individual experience were not of interest in this study. A less sensitive analytic technique that could be used is content analysis. This analysis can be conducted in a variety of ways, but is ultimately insensitive to further interpretation by the researcher (Silverman, 2011). A thematic analysis would allow for such interpretations (Braun & Clarke, 2006), which would facilitate a richer description of the use of the heuristics, and was therefore chosen to be the most appropriate analysis for this study.

For this analysis, an inductive thematic analysis was conducted, meaning that the generation of the themes was data-driven. Unlike deductive thematic analysis, inductive thematic analysis is not bound to a theoretical framework and allows themes to be generated from the data, i.e., it’s an entirely bottom-up process (Braun & Clarke, 2006). Other inductive approaches such as grounded theory, were less suitable for this study as they aim to construct theory from data, meaning that the coding system can even be entirely based on the dataset rather than being guided by the research questions (Braun & Clarke, 2013; Silverman, 2011). Because the research aims required a coding system in which the dataset was organised according to the heuristics that were used during the task, an inductive thematic analysis, which allows for such a coding system, was a more appropriate analysis for the research aims of this study. Furthermore, grounded theory is a more in-depth type of analysis than is needed for this study, which simply aimed to uncover the range of heuristics that are involved in an energy judgement.

Inductive thematic analysis allows for a descriptive account of a phenomenon (Braun & Clarke, 2013), and allows for the data to be analysed on a semantic level, meaning that themes can be identified based on the surface meanings of the data and the analysis does need to go beyond what was said in these discussions. This is in contrast with other types of thematic analyses in which the data is analysed on a latent level, such as experiential thematic analysis or constructionist thematic analysis, which go beyond the sematic content of the discussions and identifies the underlying assumptions, ideas and conceptualisations (Braun & Clarke, 2006). Similar to this study, inductive thematic analysis has been applied to generate semantic themes in another study that used stimuli to generate discussion among participants (Miles, Wheeler, & Davies, 2011).

As discussed in Chapter 1, a post-positivist approach was taken is this thesis meaning that the heuristics were assumed to already be part of the participants' cognition, and this method aimed to reveal those heuristics. Furthermore, similar to the study in Chapter 3, no inter-rater reliability tests were performed but rather this study was followed-up with quantitative methods to allow for triangulation.

6.2.5.2 Process of analysis

The process of thematic analysis, as described by (Braun & Clarke, 2006) involves six phases which is not necessarily a linear process, but involves moving back and forth between phases. The analysis process started with the familiarisation of the researcher with the data through the transcription of the discussions. Next, the data for each focus group session was carefully inspected for discussions that suggested the use of an attribute of the appliance as an indicator of its energy consumption. In other words, the data was scrutinised for heuristics that the participants employed to complete the rank-order task. For each of these attributes (or heuristics) a code was created and data that matched this heuristic was categorised under the same code. Only statements that referred to a heuristic to rank-order the appliances were coded and statements were categorised under several codes if the quotes referred to several attributes of the appliance although this did not occur frequently. Attributes that were considered by participants but subsequently dismissed were not coded as a heuristic. The heuristics were coded under overarching themes when the quotes did not match a specific subtheme.

Once the whole data-set was examined for heuristics, the coding system was completed, and subthemes and themes could be developed. Subthemes that referred to related attributes of the appliances were grouped under the same semantic thematic headings, thereby constructing the themes based on the data rather than on a theoretical framework. Subthemes and themes were reviewed and refined to make sure that (sub)themes did not overlap and were clearly defined. Next, the analysis of the entire data-set was revisited using the finalised coding system to ensure that no heuristics were overlooked and that the statements were coded in a consistent manner. Finally, the data within each subtheme was analysed by inspecting the patterns in the statements that were categorised under each subtheme.

The quotes coded under each subtheme provide both good examples of each subtheme and also served as an indication of the number of instances in which a certain heuristic was used to judge the energy requirements of household devices. Rather than presenting the number of participants or focus groups that were observed to use a specific heuristic, the number of instances in which a certain heuristic was used is presented in the findings sections as it is more likely that this count reflects the importance of the heuristic in the decision making processes. This means that the energy judgement was assumed to be influenced more by heuristics that have been observed more frequently compared to heuristics that were rarely observed in the focus groups. It is acknowledged that this assumption does not necessarily hold throughout the dataset, as influential heuristics may not always have been expressed clearly and frequently. However, the aim of this study is to map the heuristics, not to assess the relative importance of the heuristics in the decision making process. Therefore, this study does not rely on the validity of this count to reflect their true importance. The instances with which the heuristics are observed will therefore simply serve as an indication of their weight in the decision making process and will be interpreted carefully.

6.3 Findings

The following sections will report the heuristics that participants were observed to use in the rank-order task. Here, the themes and subthemes that resulted from the inductive thematic analysis are presented. Following on from this, the heuristics that were extracted from the discussion among the participants during the ranking task are compared with the heuristics the participants reported to have used. Next, an explorative, statistical analysis on the accuracy of the rank-orders of the focus groups will be reported. Finally, the responses of the participants to the correct rank-order will be briefly discussed.

6.3.1 Heuristics in energy judgement

The analysis resulted in the coding of a total of 310 instances of heuristics that were categorised into 28 subthemes, each representing a separate heuristic, and nine overarching themes were created to organise the heuristics into groups of related heuristics. Subthemes and themes are displayed in Figure 13 in which the number of instances are reported in brackets (the numbers of the themes are aggregated from subthemes). These heuristics were organised into nine themes: 1) task 2) knowledge 3) force 4) physical features of device 5) relative standing 6) temporal patterns 7) multiple consumption modes 8) temperature and 9) experience. These themes, and their subthemes, will be discussed below.

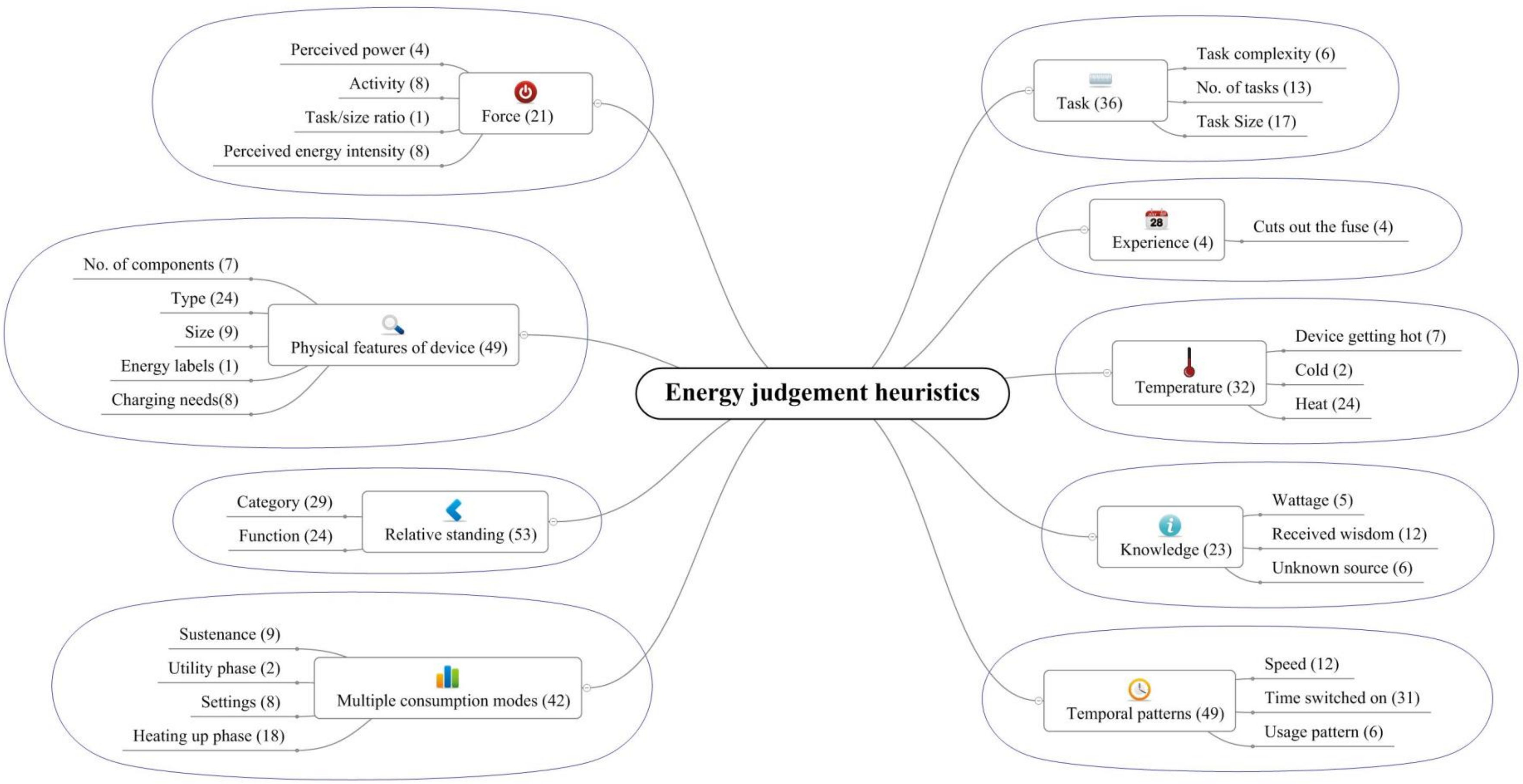

Figure 13: Mind-map of heuristics used in the rank-order task

6.3.1.1 Task (36)

This theme comprises of heuristics with which participants considered aspects of the task of the device to determine its energy use.

Task Size (17)

With this heuristic, participants judged the energy consumption by estimating the magnitude of the task which the device is to complete, i.e. ‘How much the device needs to do’:

> “*Yeah, I think DVD player uses less, because you don't use that much energy, a DVD player doesn't do much*” (Jimmy)

Devices that were perceived to carry out large tasks were expected to consume a lot of energy, as illustrated in the following quote:

> *“If you think, the kettle has to go, like make water from really cold to really hot so it has to do quite a lot of stuff... Like compared to a light: that just has to like stay switched on, it doesn't need to do anything else”* (Emma)

Task complexity (6)

The perception of the complexity of the task that the device is to carry out was used as an indicator of the energy requirements of the device. Devices that were judged to carry out complex tasks were thought to consume a lot of energy. A clear example of the use of this heuristic is given by a participant discussing the rank-order of a phone charger:

> “*Uhm, phone charger, not much? It’s easy isn't it?*” (Casper)

Although participants did not specify what they meant with the complexity of the appliance, these quotes consistently included words such as *‘easy’* and *‘only’* which indicated that they considered how difficult or complex the task of the appliance is.

No. of tasks (13)

Using this heuristic, participants judged the relative energy consumption of the devices by taking the amount of tasks of the device into account. Appliances that tend to complete several tasks (either simultaneous or successive) were expected to consume more energy compared to devices that only perform one task. This heuristic was apparent in the following quote in which a participant explicitly referred to the quantity of tasks of a coffee machine:

> “*But then, surely, coffee machine, has gotta be above kettle, because it's doing more things, than a kettle*” (Max)

This heuristic suggests that perhaps people are implicitly assuming that each task consumes a certain, relatively constant amount of energy, and therefore the total energy consumption of an appliance is the sum of each of these tasks. This heuristic can be distinguished from the task size heuristic in that this involves the consideration of the multitude of the tasks of the device rather than relating the energy requirements to the magnitude of the task of the device. Furthermore, these quotes differed from the quotes that were coded under the task complexity theme, as the current codes included explicit references to the quantity of the tasks, rather than the complexity of the task.

6.3.1.2 *Knowledge (23)*

This theme consists of heuristics in which the understanding of the energy consumption of a device is used to determine the rank of a device.

Wattage (5)

In a few instances, participants used their knowledge about the Wattage of the device to complete the rank-order task. Unsurprisingly, devices that use a lot of Wattage were judged to consume more energy compared to devices that use fewer Wattage:

> "*A microwave is about 800 Watt, that's the only thing I know*." (Jimmy)

Participants only reported to know the Wattage of a microwave, no other devices were discussed in the discussions coded under this subtheme. This is likely due to the labelling of the Wattage on microwaves and the use of the device that requires the consideration of the Wattage.

Received wisdom (12)

With this heuristic, participants used their knowledge about the energy consumption of the device that seemed to stem from public discourse about the device, for example:

> "*Portable heater take up loads of energy, someone told me that*." (Casper)

This quote demonstrates how a participant inferred the energy use from what he was told about the energy use of the appliance. Furthermore, participants inferred the energy use of appliances from what they had heard about the curtailment of appliances, meaning that when they had heard they should switch off an appliance to save energy, the appliance was perceived as energy draining.

Unknown source (6)

In some instances participants were confident about their estimate of the energy use of the device but did not articulate the source of this hunch. This subtheme was evident in a participant's response to another participant's request to explain her suggestion of the rank of the hoover:

> *"I think hoover uses a lot, just general knowledge I think."* (Jimmy)

6.3.1.3 Force (21)

Under this theme, heuristics were categorised that involved the perception of the force of the device such as its intensity, activity, perceived power and task to size ratio.

Perceived energy intensity (8)

This heuristic involved the perception of the energy intensity of the device to determine its rank among the other appliances. When a device was perceived as less energy intense, it was expected to use less energy compared to devices that were perceived to be more energy intense. For example, when discussing the position of a tumble dryer and a hob, a participant expressed:

> "*I think they'll be quite energy intensive so let's put it there [pointing to the top of the ranking-order]."* (Jimmy)

Within this subtheme, participants discussed a general feeling for the intensity of the energy use. This subtheme differs from the Wattage theme as these quotes did not involve explicit referrals to the exact amount of Wattage an appliance uses.

Perceived power (4)

The perceived power with which a device functions was used as an indication of its energy consumption. This heuristics was evident in the following quote that includes an explicit referral to the power of the appliance:

> "*Do you think like, because game systems and computers are quite powerful, aren't they?*" (Steve)

When a device was perceived as using a lot of power, participants placed the device higher in the rank. However, what exactly constituted a powerful device was not clear from the statements of the participants, as they referred to the power in ambiguous terms, and did not make explicit references to Wattage.

This subtheme differs from the perceived energy intensity subtheme that refers to discussions about the energy intensity of an appliance whereas the discussions coded under perceived power included explicit references to the powerfulness of the appliances. Furthermore, similar to the energy intensity theme, this subtheme differs from the Wattage subtheme as it includes more ambiguous references to the power of an appliance rather than an explicit amount of Wattage a device uses.

Activity (8)

Participants used the level of activity of the device as an indicator of its energy requirements. When a device was perceived to be more active than other devices, the device was thought to consume more energy. For example, a participant argued that an appliance did not belong to the group of high energy consuming appliance that were placed at the top because "*They are not active as these things*" (Alia). Within this subtheme, participants tended to focus on the activity level of the device itself rather than the task that needs to be completed by the device, and this heuristic therefore differed from the task size heuristic.

Task/size ratio (1)

The ratio between the task size and the size of the device was considered by the participants to determine its relative energy consumption. Devices that are small but conduct a large task were thought to use the most energy:

> "*Because that heats up everything around it, and it's only a small thing, so it's probably more likely to create more heat quicker [others agree] than*'" (Kevin)

Within this subtheme, participants explicitly referred to the ratio of the device's task and size, meaning that, the smaller the device and the more tasks it completes, the more energy it requires.

This theme differs from the intensity theme in that responses that were coded under this heuristic explicitly referred to the ratio of the device's task and size, whereas discussions coded under the intensity subtheme concerned discussion of the energy intensity of the device. Moreover, this heuristic differs from the size heuristics with which participants only tended to take the size of the appliance into account and not the relation of the appliance' size to the appliance' task.

6.3.1.4 Physical Features of Device (49)

Within this theme, heuristics were included with which participants used the visible characteristics of the device to determine how much energy the device uses.

No. of components (7)

The amount of components of the device was used as an indicator of its energy consumption. Devices with a lot of components were judged to use more energy compared to devices with fewer components:

> "*Because you have a DVD player in your laptop, so a laptop with a disc driver is going to have more than a DVD player*." (Jimmy)

Within this heuristic, participants explicitly referred to the amount of physical modules of the device, rather than the number of tasks a device needs to perform and therefore this heuristic differs from the number of tasks heuristic.

Type (24)

Participants considered the type of device or brand of the device to rank the household appliances, assuming that devices from some brands or certain type of devices are more energy consuming. For example, a participant argued that the energy use of a coffee machine depends on the type of coffee machine:

> "*…it really depends on what kind of coffee machine you take this for. If it's one of those technical ones, than, yeah, it will probably be high, if you look, probably, a regular probably wouldn't take that much energy*." (Jo)

Other participants discussed how different makes of vacuum cleaners were more or less effective, and this variability would have affected the energy consumption.

Participants particularly discussed the energy efficiency of the household devices rather frequently. Appliances that were perceived as more energy efficient were expected to consume less energy compared to other appliances. Most of the discussions of the energy efficiency of devices concerned energy saving light bulbs.

Size (9)

The size of the appliance was used to estimate its energy consumption. Larger devices were judged to consume more energy compared to smaller devices:

> "*Well, maybe the smallest things use the least"* (Emma)

Moreover, when a participant argued that a kettle would use more energy than an oven because it heats up more quickly another participant responded "*But it's smaller than an oven..."* (Cloé) implying that the size heuristic was perceived to be a more valid heuristic than the speed of heating up-heuristic. This heuristic differs from the number of components heuristic because it considers the mere size of the device rather than the multitude of the elements of the device.

Energy labels (1)

The presence of an energy label on a household device was considered to be an indicator of the level of energy consumption:

> "*Because fridges have those things where they have to tell you how much energy they use and stuff whereas phone chargers...*" (Alia)

When a device usually had an energy label, it was expected to use more energy than devices that did not have this label. This is an interesting finding as the labels are intended to encourage the purchase of low-carbon appliances, but if people see them as warnings (and see their absence as a sign of low consumption) then these labels may not be effective. This heuristic, however, was only observed once and therefore this heuristic may not be widely used.

Charging needs (8)

Whether the appliance requires charging was also considered during the rank-order task. Some quotes suggested that participants perceived appliances that are re-charged to use more energy:

> *"Phone charger, well chargers might need quite a bit because they're charging something*." (Olivia)

However, other quotes did not reflect how this attribute influenced their energy judgement:

> "*And electric toothbrush, how does that work? I mean, that was electric, so it charges doesn't it?* " (Steve)

Therefore, the use of this heuristic was not necessarily clear-cut and may have been used bidirectional.

6.3.1.5 Relative standing (53)

Within this theme, participants used heuristics that involved the explicit comparison of different features of the appliance to determine its relative standing among the devices regarding energy expenditures.

Category (29)

Participants grouped together devices that tend to be associated with each other, for example:

> *"I think that...the washing machine and the tumble dryer are gonna be similar.*" (Emma)
>
> "*DVD player and TV would be quite similar I think*". (Ciaran)

These quotes show how participants inferred that appliances that are semantically related to each other consume similar levels of energy use. That is, appliances that belonged to a similar 'category' (e.g. entertainment, laundry) were thought to use a similar amount of energy. Knowledge or perception of the energy use of one device could spill over into energy perceptions of devices that were classified in the same category. It needs to be noted however, that the use of this heuristic was never explicitly stated by the participants and the use of this heuristic is therefore an interpretation of the researcher.

Function (24)

The function of the device was considered to determine the relative energy consumption of the appliance. More specifically, participants grouped the devices either on function similarity or function dissimilarity.

When participants grouped devices with similar functions, knowledge about the energy requirements of one device could spill over onto devices with similar functions. For example, while discussing the rank of the DVD player, a participant said:

> "*Next to stereo because they do the same thing..*." (Emma)

Within this heuristic, participants explicitly referred to the function of the device, such as heating up water. This heuristic therefore differs from the category heuristic with which participants grouped together devices that are associated with each other but do not necessarily have the same function.

Participants also contrasted the energy consumption of functions of different devices to distinguish the energy demand of the appliances:

> *"I don't know if it take more energy to wash or dry something"* (Alia)

This quote shows how a participant attempts to compare the energy use of a tumble dryer and washing machine by contrasting their functions.

6.3.1.6 Temporal patterns (49)

The heuristics that were categorised under this theme relate to several time-related properties of the appliance that were considered to determine the appliances' energy use.

Speed (12)

Participants used the speed with which the device accomplished its task as an indicator of its energy consumption:

> Kevin: "*Microwave uses a lot more than like a kettle, or coffee machine*"
> Cloé: "*Yeah, cause it's a quick, like, process isn't it?*"

This interaction between participants shows how participants thought that the faster the device tends to complete its task, the more energy the device was thought to consume.

Time switched on (31)

This heuristic involved the judgement of the energy consumption of a device by the amount of time for which a device is commonly switched on for:

> "*I think, it must be like, fridge freezer, must not use a lot because they are on all the time*" (Minnie)

When a device is generally switched on for a longer period of time, the device was thought to consume low levels of energy. However, this heuristic has also been used in a negative direction in one instance. That is, when the participants discussed the rank of an electric blanket a participant noted:

> "*Quite high isn't it? Because you don't have it on all the time.*" (Jo),

This quote shows how the participant judged an appliance not to use much energy because it is not switched on much.

Participants elaborated on the reasons that underpinned the use of the time switched on heuristic. First, they explained the use of this heuristic by arguing that when a device that is generally switched on for a long time, is a necessary item in the household, the device could not be switched off, and therefore, could not use a lot of energy:

> "*Because you can't turn your fridge off, so you can't save energy*" (Emma)

This implies that the more necessary a device was thought to be, the more energy it was perceived to use, because necessary appliances that are switched on a lot are expected to consume a reasonable amount of energy.

Moreover, participants reasoned that if a device was switched on continuously, it was expected that it could not use a lot of energy because that would imply that the device would be very expensive to run. Thus, participants reasoned that appliances that are switched on much cannot use a lot of energy per minute because otherwise it would cost too much to run the device.

Usage pattern (6)

Participants considered how often and for how long a device is generally used to determine its energy use. Devices that are rarely and shortly used were thought to use more energy:

> "*I think hair dryer is going to be higher, I think, cause you don't use a hair dryer that much...*" (Cloé)

Within this heuristic, the amount of energy perceived to be used lay in the amount of human interaction with the device, and thereby distinguished itself from the time switched on heuristic. Meaning that, the less interaction with that device, the lower the perceived energy usage was.

6.3.1.7 Multiple consumption modes (42)

This theme includes the heuristics with which participants took the variability of a task process of the device into account. That is, participants discussed how appliances can use different levels of energy in different phases (such as a maintenance phase, a utility phase or heating up phase) of the use of the appliance.

Sustenance (9)
To determine the rank of the device, participants considered whether a device needs to maintain a certain level of heat/movement/etc, for example:

> "*I'd start with the freezer or the oven*. [others agree] *either of those two because they have to maintain...*" (Jess)

The usage of this heuristic seemed to be directional. On the one hand, devices that 'keep up the heat' or movement were judged to consume more energy compared to devices that do not have this feature. Conversely, devices that tend to have a phase in which a certain level of heat or movement needs to be maintained were judged to use lower levels of energy, as the main proportion of energy was perceived to go into getting the device to the sustenance phase.

Utility phase (2)
The phase in which the device tends to be used was also considered when determining its energy use. For example, when discussing the energy use of an iron, participants discussed:

> Ciaran: *"Because you have to warm up the iron, and then you stop kind of"*
> Minnie: *"It can't use that much, once it's warmed up..."*

This interaction shows how participants considered that after an initial heating up phase, the iron would not use that much energy while in use. That is, in the utility phase, the device was thought to use less energy compared to its use in a 'preparation phase'.

Settings (8)
With this heuristic the settings of the device were considered to determine its energy consumption. For example, when discussing the energy use of an electric blanket, a participant said:

> "*I think it's a dial so it can stay at like temperature 5 or whatever. I think with a microwave it's more than that.*" (Minnie)

This quote shows how participants compared the energy use of an electric blanket with the use of a microwave by comparing the range of settings of the appliances. When the device can be set on a higher unit (e.g. higher temperature) the device was thought to use more energy than other devices that have lower settings. However, in some instances, the settings were simply taken into account, and the discussions did not show how it informed their energy judgement.

Heating up phase (18)

Participants considered whether a device needs to heat up to determine its relative energy consumption. For example, when discussing the energy use of an iron, a participant noted:

> "*It does have the initial heating up period, I guess, which it tends to do quite quickly. I guess, if you think of how quickly they work, the proportion to that…"* (Steve)

Devices that have an initial heating up phase were judged by the participants to consume more energy compared to devices that do not have this feature. Furthermore, the speed of the heating up process was used as an indicator of its energy use. This heuristic was used in both directions: devices that were judged to heat up slowly were judged to use a lot of energy. For example, when discussing which devices should be ranked on the top a participant expressed:

> "*How about the electric hob? Because that takes a while to warm up.*" (Jo).

However, when the same device was judged to heat up quickly in a different focus group, the device was also judged to use a lot of energy.

This heuristic differs from the speed heuristic as with that heuristic, the task completion speed is only considered, which does not specifically include an initial heating up period but rather considers the entire task of the device.

6.3.1.8 Temperature (32)

This theme comprises of heuristics that focus on the thermal properties of the devices. This theme, and its subthemes are distinct from previously discussed themes that involved temperature aspects, such as the heating up phase heuristic, as the quotes here focused on the effect of the temperature change on the energy consumption directly, rather than considering that appliances may use more energy during a heating up phase compared to its other phases.

Device getting hot (7)

Using this heuristic, participants considered whether the device itself gets hot when in use, to estimate its energy use.

> "*Like laptop and things might use quite a lot. Because they get so warm after like, after a couple of minutes with like, all the energy they are making*" (Ciaran)

When a device gets hot when it is switched on, it was judged to use more energy compared to devices that do not heat up. This heuristic involved devices that get hot as a product of their functioning, such as a laptop, rather than it being the aim of the device, such a radiator.

Heat (24)

Devices that aim to heat up air or water were thought to use a lot of energy:

> "*The ones that produce heat, are gonna be high up, aren't they, they use a lot of energy, like things that produce heat use the most, so that's going to be high up.*" (Hannah)

This quote shows that devices that heat up an element, such as water, were considered to use more energy compared to devices that do not. Moreover, appliances that produce more heat than other appliances were judged to consume more energy, For instance, one participant compared the energy use of a kettle with a portable heater:

> "*If you think about how much heat it's creating, its boiling water, in a minute, you can't boil water off a heater"* (Emma)

Within this heuristic, participants placed emphasis on whether a device increases the temperature of air, water or a surface as to how much energy it used, which differs from the heating up phase heuristic in which only the phase in which the device heats up is considered. Furthermore, this heuristic differs from the device getting hot heuristic because that heuristic considers whether the device itself gets hot, rather than the air or water as a function of the operation of the device.

Cold (2)

Appliances that aim to reduce the temperature of an element such as air or water were also judged to consume high levels of energy. For example, a participant judged a fridge to use a lot of energy because:

> "*They have to keep it at a very cold temperature*" (Nico)

6.3.1.9 Experience (4)

This theme covered a heuristic that involved the participants' experience with the device.

Cuts out the fuse (4)

Participants considered devices that had previously cut out the fuse box to be high energy consuming devices. The use of this heuristic is evident in the following quote in which a participant discussed the energy use of a hairdryer:

> "*So I* [think] *high, because in my room, always, it always cut's out the fuse... so...*" (Emma)

Participants felt that devices were more likely to consume more energy if they had caused a shorting in the fuse box, suggesting that they thought the high levels of energy use of the appliance caused the incident.

6.3.2 Awareness of the use of heuristics

After the completion of the rank-order task, participants were asked how they had conducted the task. These discussions were coded using the same coding system that was developed and used in the previous analysis, to compare the observed and reported heuristics. Only the subthemes were included in this analysis as these reflected the heuristics that were used whereas themes were merely constructed to organise the heuristics in the previous analysis.

Participants' discussions matched 14 of the 28 observed heuristics, including the size heuristic (Emma: "*The appliances that are the smallest, would tend to use less energy than the ones that were the biggest...*"), the heat heuristic (Jimmy*: I think we just used how much heat it uses* [others agree], *for the top ones.*"), and the activity heuristic (Alia: "*...the things that use more like activity are kind of at the top*").

Much fewer instances of reported heuristics were found (33) compared to the number of instances that heuristics were observed to be used during the ranking order task (310), which is not surprising as participants made a number of judgements during the tasks within which heuristics can have been repeated. Therefore, to be able to compare the relative frequency with which the heuristics were reported and observed, the heuristics were rank-ordered according to the frequency with which they were observed and reported (see Table 9). After this, the ranks of each heuristic could be compare to assess participants' awareness of the use of the heuristics during the task.

Table 9: Ranks of heuristics by frequency of observed and frequency of reported

Heuristic	Rank observed (No. of instances)	Rank reported (No. of instances)
Time Switched on	1 (31)	7 (2)
Category	2 (29)	- (0)
Heat	3 (24)	3 (4)
Function	4 (24)	8 (2)
Type	5 (24)	- (0)
Heating up phase	6 (18)	- (0)
Task size	7 (17)	13 (1)
No. of tasks	8 (13)	4 (3)
Speed	9 (12)	9 (2)
Received wisdom	10 (12)	- (0)
Size	11 (9)	1 (5)
Sustenance	12 (9)	- (0)
Settings	13 (8)	- (0)
Activity	14 (8)	5 (3)
Charging needs	15 (8)	- (0)
Perceived energy intensity	16 (8)	2 (5)
No. of components	17 (7)	- (0)
Device getting hot	18 (7)	- (0)
Task complexity	19 (6)	14 (1)
Usage pattern	20 (6)	11 (1)
Unknown source	21 (6)	- (0)
Wattage	22 (5)	12 (1)
Perceived power	23 (4)	10 (1)
Cuts out the fuse	24 (4)	- (0)
Cold	25 (2)	- (0)
Utility phase	26 (2)	- (0)
Energy labels	27 (1)	- (0)
Task-size	28 (1)	6 (2)

The heuristics that were most often reported by participants were the size heuristic (5 instances) and intensity heuristic (5 instances) whereas these heuristics ranked 11th and 16th in the list of most frequently observed heuristics. This therefore showed a clear discrepancy in the relative frequency with which these heuristics were observed and reported. Nevertheless, the heat heuristic was ranked third for both reported and observed heuristics, thereby matching in ranks. Further, the category heuristic was the second most frequently observed heuristic, but was not reported by the participants at all. Moreover, the most often used heuristic, which was the time switched on heuristic (31), was only reported twice.

These findings therefore suggest that, first of all, participants may not have been aware of half of the heuristics that they employed during the rank-order task, as only 14 of the 28 observed heuristics were reported. Furthermore, the relative frequency with which the heuristics were reported did not match the relative frequencies with which they were observed.

6.3.3 Accuracy of rank-order

To get a sense of the performance on the rank-order task, and thereby a sense of how well the heuristics worked for people, a correlational analysis was conducted to compare the rank-order that the participants produced with the correct rank-order. This analysis was not planned before the study was conducted and therefore the outcome of the rank-order task was only coincidentally recorded for four groups. Because the aim of current analysis is solely to get a sense of the accuracy of the task, and thereby to contextualise the use of the heuristics, only tentative conclusions will be drawn from this analysis.

Similar to Baird and Brier (1981), the median rank-order was computed for each appliance between the rank-orders of the different groups, and a spearman correlation between this variable and the 'correct' rank-order variable was computed. Results showed that participants' rank-order correlated strongly with the true rank-order ($r_s = .72$, $p<.001$), see Figure 14. These results show that participants were fairly successful at rank-ordering the household appliances, although their performance was still considerably far away from perfect. The appliances that were mis-ranked the most were washing machine (M_{dif}=9.00), electric blanket (M_{dif}=8.50), and fridge freezer (M_{dif}=7.50), which all tended to be ranked much higher than was accurate.

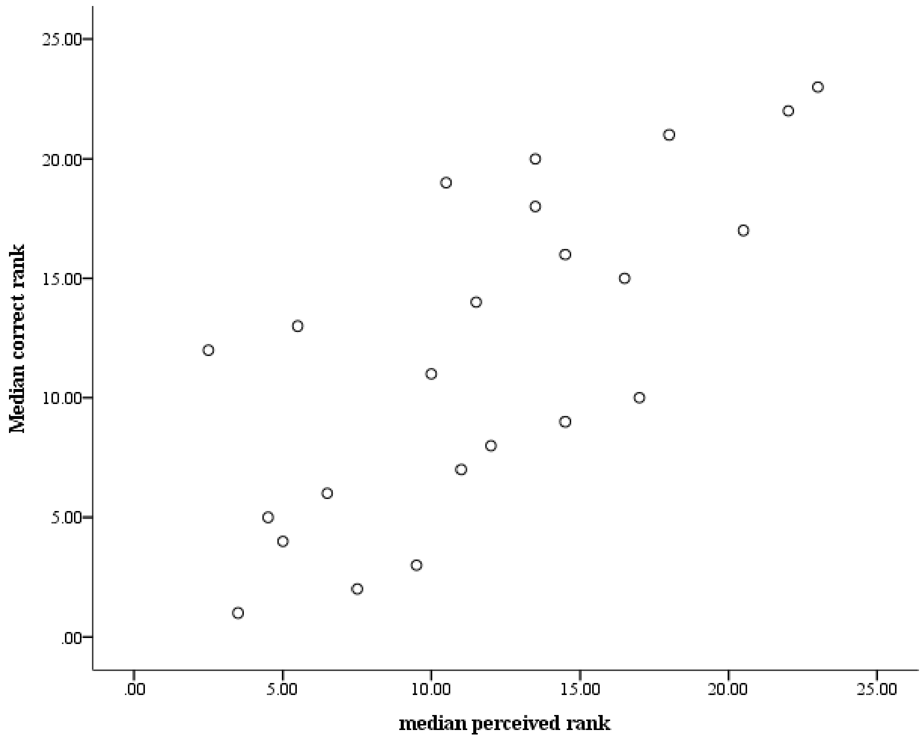

Figure 14: Scatter graph displaying the median correct rank and median perceived rank of household appliances

6.3.4 Responses to 'correct' ranking-order

The analysis in the last section suggested that participants completed the rank-order task fairly successfully. To investigate people's perceptions of their energy judgement, the focus groups were shown the 'correct' rank-order after they had completed the task. A thematic analysis was conducted to investigate patterns in their responses. Of specific interest was how participants would explain discrepancies between their rank-order and the correct rank order and whether these discrepancies would be attributed to the use of the heuristics. Therefore, a mixture of inductive thematic analysis (constructing themes based on the data set) and deductive thematic analysis (constructing themes based on these research aims) was applied. The thematic analysis resulted in the following themes: performance evaluation, correctly judged devices, misjudged devices, explanations for misjudgement and alternative strategies. Each theme will be described in the next few sections.

Most of the quotes coded under performance evaluation conveyed a positive appraisal of the group's performance on the task. The statements seemed to match the actual performance (as reported in section 6.3.3) fairly adequately as participants expressed to be modestly satisfied with their results (Steve: "*I think we did alright, a lot of the items in the top 10 we also got in the top ten, so…*"), although some statements were more positive (Casper: "*We smashed it guys*!"), or more negative (Max: "*We got the lasts ones right at least*") which may be due to the variation in performance across the groups.

Participants tended to identify the items they had ranked correctly and the appliances of which they were surprised to learn about their correct rank. Appliances that participants most often identified as having judged correctly were tumble dryer, electric toothbrush, and phone charger. These items were the highest and lowest items in the correct ranking-order which may have facilitated the comparison of the correct rank of these appliances with the participants' rank-order. The items of which participants expressed to be surprised of its correct rank most frequently were kettle (which was mentioned 6 times as consuming more energy than expected), electric blanket (which was expressed 6 times to be ranked lower than expected), and oven (which was ranked higher than expected in 6 instances). Note that this is only in part congruent with the findings in the last section as only the electric blanket of these three appliances was identified to be misjudged most often.

When participants inspected the correct rank-order list, participants used this list to infer which heuristics would have been (more) helpful in completing the task (24 instances). That is, during these discussion participants referred to as much as 13 types of heuristics that were previously observed during the rank-order task that could account for the correct ranking order. The heuristics that were most frequently proposed to explain the energy use of appliances included heat (Ted: "*Its things that change the temperature*"), task size (Alia: "*Yeah, I suppose* *it's a big area they are heating up, thinking about that.*") and necessity ("*The stuff on the top are the things we need every single day, the stuff at the bottom you don't always use.*").

Furthermore, participants' explanations for the misjudgement of the devices were attributed to the following: 1) infrequent use of the device (Olivia: "*I haven't used those in a while so.*."), not owning the device (Alia: "*Yeah, you can tell none of us own an electric blanket*"), 2) short usage of the device (Emma: "*It seems like, those things, you just turn them on for a couple of minutes*) [..] If: *yeah, and you don't realise how much energy they consume*"), 3) lack of knowledge about the energy consumption of the device (Minni: "*We don't have much knowledge about electrical appliances? That's the issue here*..." or about the operation of the device (Casper: "*We don't understand…"Max: "How they work!")* 4) a discrepancy between the unit of time considered in the task and the use of the device (Steve: "*I guess you don't really think about it as using that much energy because that's probably on for an hour"*), 5) participants admitted that their decision making process did not involve deep processing (Casper: "*Yeah, I guess we didn't think it through enough.*") and, most importantly, 6) previously used heuristics were invalidated:

> "*Uhm... we probably, we thought, if it was on for a long time it would be using less energy... Often. And that wasn't the case.*" (Ciaran)

6.4 Discussion

In the following sections, the findings will be interpreted and their implications will be discussed. Furthermore, limitations of the study and directions for future research will be discussed.

6.4.1 Discussion of findings

6.4.1.1 Heuristics in energy judgement

The most striking finding of this study is the vast complexity of the decision making process in the energy judgements of the participants. The discussions of the participants that was generated by the ranking task could be classified into 28 distinct heuristics that have been organised into nine overarching themes. These findings, therefore, suggest that people use a lot more attributes of the device as indicators of the device's energy use than previously thought. Previous research has reported a size heuristic (Baird & Brier, 1981; Chisik, 2011; Schuitema & Steg, 2005) a usage pattern-heuristic (Chisik, 2011) and suggested a visibility-heuristic (Schuitema & Steg, 2005) to influence the decision making process in energy judgements. The latter heuristic was not observed during the rank-order task, and because Schuitema and Steg also did not provide robust support for the use of this heuristic, it is likely that this is not a (commonly) used heuristic in energy judgements. Although participants were not found to use the visibility heuristic, the use of the size- and usage pattern heuristic was confirmed in this study. More importantly, the findings suggest that these heuristics alone cannot account for energy judgements. Previous research seems to have only identified the minority of numerous heuristics that are involved in this decision making process as the size and usage pattern heuristics together only make up (2/28=) 7.1% of the total number of heuristics that were used in the current study. Moreover, these two heuristics were not the ones that were used most frequently; in the present study, the size heuristic and the usage pattern ranked as the 11^{th} and 20^{th} most frequently used heuristics respectively.

The most frequently observed heuristics were time switched on, category and heat. Of these heuristics, the time switched on heuristic was the most commonly observed heuristic, despite the fact that participants were clearly instructed to judge the energy consumption for one minute of continuous use, so that the estimate was independent of the amount of time a device is generally switched on, or used for. It is possible that the participants disregarded these instructions and therefore considered the temporal aspects of the devices. This would mean that participants confused the ‘area under the curve’ in which one judges the energy device dependent on the surface under the curve ignoring whether this area is vertical (indicating the energy consumption at a certain time point) or horizontal (indicating the energy consumption over a long time period). Moreover, general discussion about the energy use of appliances might often relate the energy consumption to usage frequency rather than how much it uses per unit of time. Therefore, participants may be more accustomed to this way of discussing energy consumption of devices. Indeed participants often indicated to have difficulties with the task instructions.

However, closer inspection of the discussions relevant to this heuristic revealed that participants did seem to follow the instructions of the task, and provided a rationale for the use of this heuristic. That is, participants argued that when a device is switched on all the time, the device is not expected to use a lot of energy per minute as this implies that it would cost a lot of energy to run the device. Two assumptions underpinned the use of this heuristic. First, they assumed that the technology of energy draining appliances would be innovated to make the appliances more efficient. Second, participants assumed that energy draining appliances would not be switched on for a long period of time as it would be too costly to run them for this long, and therefore appliances that are switched on continuously cannot use a lot of energy per minute. Note that this line of reasoning seems to rely on the assumption that action would have been taken if (essential) household appliances consume a lot of energy (e.g. innovation or perhaps an authority would ban the use of these appliances). This corresponds to research demonstrating that individuals who do not identify themselves as environmental activists ascribe the responsibility to tackle environmental problems to external agents such as the government or business (Harrison & Burgess, 1996). Furthermore, the fact that participants elaborated on, and justified the use of this heuristic, suggests that this heuristic was used deliberately rather than unconsciously.

The category heuristic involved the grouping of appliances that are associated with each other and the assumption that these appliances consume similar levels of energy. The validity of the heuristic can be disputed as there should not be any reason why appliances that are associated with each other would consume similar levels of energy. Nevertheless, this heuristic was not expressed by participants explicitly, but was observed by the researcher. This therefore suggests that this heuristic is not used deliberately but instead, unconsciously. Alternatively, it is possible that the use of this heuristic was a misinterpretation from the researcher.

The other most commonly observed heuristic was the heat heuristic. The use of this heuristic implies that participants perceived a positive relationship between the extent to which an appliance functions to increase the temperature of water or air, and its energy consumption. This heuristic may be a more valid way of judging the energy use of an appliance and result in accurate energy judgements. Indeed, the production of heat requires a high level of energy which is evident in the fact that the top energy draining appliances in the correct rank-order are dominated by heat producing appliances (tumble dryer, oven, kettle, electric hob, and heater, see Appendix).

The discussions and use of many other heuristics suggested that these heuristics have not received extensive consideration and may be used unconsciously. One indicator of the heedless use of the heuristics is the bidirectional use of some heuristics. In other words, participants have taken the presence of the attribute feature as an indicator of both low and high levels of energy consumption. For example, when participants used the speed heuristic, devices were perceived as using a lot of energy when they complete their task quickly as well as slowly.

6.4.1.2 Awareness of the use of heuristics

The comparison of observed and reported heuristics showed that participants only reported half of the heuristics that were observed to be used during the decision making process. This suggests that participants may be unaware of a large number of heuristics and the variety of the heuristics that they had employed in the ranking-order task. Moreover, participants did not report the use of the heuristics in a way that reflected their relative use. This suggests that participants did not have good knowledge of the relative importance of the energy judgement heuristics in their decision making, although it is acknowledged that the frequency does not necessarily reflect the importance of the heuristic in the energy judgement. More specifically, participants seemed to be particularly unaware of the importance of the category heuristic and the time switched on heuristic, as these were hardly reported, despite being often observed. Conversely, heuristics that were frequently reported such as size and energy intensity, were not observed as frequently during the task, except for the heat heuristic.

The inconsistency between the observed and reported heuristics may be indicative of the deliberateness with which the energy judgement heuristics were used. That is, people are not good at reporting the use of heuristics that are employed unconsciously (Chaiken, 1987; Chaiken, 1980). Therefore, the heuristics that were not spontaneously reported by participants when they were asked about their strategies for the task may represent heuristics that are used in a more automatic and unconscious fashion. As such, both conscious and unconsciously used heuristics may have been observed during the rank-order task, but the reported heuristics may only reflect the heuristics that participants were aware of and these are therefore likely to have been used more deliberately. This would imply that heuristics such as the size heuristic and the energy intensity heuristic are used deliberately, whereas heuristics that have not been reported by participants at all, such as the category heuristic, are used unconsciously. This would be in line with the notion that some heuristics tend to be used consciously whereas others are used without conscious awareness (Goldstein & Gigerenzer, 1999; Kahneman & Frederick, 2001).

The heuristics that have been identified in previous research, the size and usage pattern heuristics (Baird & Brier, 1981; Chisik, 2011; Schuitema & Steg, 2005), were both reported by participants in the current study and therefore seem to be used in a deliberate fashion. The methods that were used in previous research to assess the use of energy judgement heuristics may have only facilitated the uncovering of heuristics that are used consciously. That is, in these studies, participants rated the appliances on the heuristic attribute and may therefore have been able to indicate the use of the heuristics that they were aware of. This would explain why so few heuristics have been uncovered in previous research and why these heuristics are the ones that participants in this study also reported to have used.

6.4.1.3 Accuracy of rank-order

The rank-order that was created by participants was found to strongly correlate with the correct rank-order of the energy use of the appliances. This suggests that participants were fairly successful at rank-ordering the household appliances in terms of energy consumption. This finding sits in line with the results of the study by Baird and Brier (1981) in which the correlation between the perceived rank-order and correct rank-order ($r_s = .81$) was very close to the correlation found in the current study ($r_s = .72$). Hence, this study supports Baird and Brier's finding that people are reasonably accurate at estimating the energy consumption of household appliances. However, it needs to be noted that this was only an exploratory analysis as there was not sufficient data to generalise these findings beyond this study. Therefore, this finding should be interpreted as an indication of accurate energy perceptions, but no firm conclusions can be drawn.

6.4.1.4 Responses to 'correct' ranking order

Although participants were fairly satisfied with their performance on the task, the correct rank-order of the appliances was received with a lot of interest by participants who showed willingness to learn from the task and improve their energy perceptions. As such, participants mainly identified appliances that were ranked incorrectly by the group, although some correctly ranked items were also identified. Participants generated a range of explanations for the misperceptions of the energy consumption of the appliances, which in a few occasions meant that participants invalidated heuristics that they had used in the task. Interestingly, participants used the correct rank-order list to infer which heuristics would have been (more) helpful in completing the task. This further demonstrates participants' awareness of the use of these heuristics. The eagerness of participants to improve their energy perceptions is very promising. This is in line with a previous survey in which participants reported to be interested in receiving information on household energy use (Mansouri et al., 1996).

Moreover, this is the first study that has investigated people's perceptions on the use of energy judgement heuristics and findings show that when participants reflected on their energy judgements, they considered the validity of the heuristics that they had used in this task This suggests that they may be motivated to address the use of heuristics to improve their device energy literacy. These findings therefore imply that people can change their perceptions of the validity of the energy judgement heuristics. Furthermore, this raises the question if the use of these heuristics will change following the changes in the perceptions and awareness of the heuristics, and whether this change in the use of heuristics, then in turn can enhance device energy literacy.

6.4.2 Implications of findings and future research directions

Although the comprehensive list of energy judgement heuristics that have resulted from this study is striking, the heuristics used by these participants may not represent the population at large. That is, these participants did not pay for their energy bills which may have caused them to have lower levels of energy literacy compared to a population that is responsible for their electricity bills, although this has not been established in previous research. With this in mind, one must be careful drawing firm conclusions despite the striking findings that illustrated the complexity of energy cognition. The list of heuristics that resulted from this study may not be exhaustive and their relative importance could not be accurately assessed with the qualitative methods in this study. A follow-up study is therefore needed to verify and further explore these findings.

This study suggests that people may be more aware of the use of some energy judgement heuristics than others, and therefore this awareness of the energy judgement heuristics was further investigated in the study reported in Chapter 7. That is, the study reported in the following chapter used quantitative methods that investigated people's ability to recognise the use of the energy judgement heuristics that were identified in the current study, to assess the different levels of awareness of the heuristics. Furthermore, because the findings reported in this chapter suggests that people might be willing to change the use of invalid energy judgement heuristics, the study reported in Chapter 8 explored if informing people about the validity of energy judgement heuristics can improve energy literacy and energy conservation.

6.4.3 Conclusion

This study showed that energy judgements are more complicated than has been assumed in previous research. That is, previous studies only identified two types of heuristics that are employed in this decision making process whereas the current study identified 28 different heuristics. Furthermore, the discrepancy between observed and self-reported heuristics shines some light on how these heuristics may be used. As such, some heuristics may be used in an automatic and unconscious fashion, whilst others seem to be used deliberately and are justified using rational thought. Although people might be fairly successful in judging the energy use of household appliances, there is room for improvement which may be addressed by changing the use of these heuristics. This study shows that people might be eager to improve their energy literacy and acknowledge the role that these heuristics play in their energy judgement. Hence, this study suggests that improving energy literacy should perhaps focus on stimulating the adoption of more valid heuristics and the discontinuation of the use of heuristics that do not benefit the accuracy of the energy judgement.

Chapter 7: Quantifying the Awareness of Energy Judgement Heuristics

The previous qualitative study showed that many heuristics were used in an energy judgement task, but participants only recalled using half of these heuristics. This study aimed to further explore people's awareness of these energy judgement heuristics by investigating to what extend participants recognise their use when explicitly prompted. Furthermore, the complexity of the decision making process was explored by assessing how many heuristics participants report to use in each energy judgement. Participants (N=248) conducted a series of energy judgement tasks in an online survey and indicated which of the previously identified heuristics they had used to arrive at their estimate. To organise the heuristics into groups of different levels of awareness, a cluster analysis was performed on the frequency with which heuristics were reported to have been used. Results indicated that participants were most aware they used the heat and time switched on heuristics, whereas the heuristic that was one of the most frequently observed to be used in the previous study, the category heuristic, was least recognized by the participants. These results further suggest that the awareness of the use of the heuristics may differ across heuristics, which may indicate differences in the deliberateness with which the heuristics are used. Furthermore, participants were found to report to use three heuristics per energy judgement, and this number varied widely across participants and appliances, suggesting that this decision making process is fairly complex.

7.1 Introduction

In the study discussed in Chapter 6, participants were observed to use a wealth of energy judgement heuristics to complete an energy judgement task. This study therefore suggested that this energy judgement is elaborate and complex, and that people engage in extensive deliberation to arrive at their energy estimate. At the same time, participants seemed unaware of the use of many heuristics, suggesting that these decisions may involve automatic, unconscious processes. The current study aimed to further investigate this energy judgement process by examining people's awareness of the energy judgement heuristics and the complexity of this decision making process.

7.1.1 The awareness of energy judgement heuristics

Although previous research (Baird & Brier, 1981; Chisik, 2011; Schuitema & Steg, 2005) has identified only two types of heuristics that are employed when judging the energy consumption of home appliances (the size heuristic and usage pattern heuristic), the study reported in Chapter 6 suggested that people might use as many as 28 different heuristics in this process. However, when participants were asked how they estimated the energy consumption of household appliances, only 14 of these heuristics were reported. This discrepancy between the number of heuristics that were observed to be used in the energy estimation task and the number of heuristics that participants reported, suggested that people may not be very aware of the use of all the heuristics that they employ in energy judgements. That is, the study in Chapter 6 suggested that participants were only aware of half of the heuristics that they had used in their decisions. However, this study did not show whether people were completely unaware of the other 14 heuristics, or whether the reported 14 heuristics were simply more salient as this method relied on participants spontaneously referring to these heuristics which requires a high level of awareness of the heuristics.

It is important to further investigate the awareness of the energy judgement heuristics as this understanding will illuminate how the heuristics are used and which heuristics may be most influential in energy judgements. The current study therefore further investigated the awareness of these heuristics by simplifying the process of introspection. Specifically, this study examined to what extent people recognize their use of the heuristics by prompting participants with the energy judgement heuristics that were observed in Chapter 6. The extent to which participants recognize using a heuristic was taken as a measure of the extent of the participants' awareness of using these heuristics. Because recognizing the energy judgement heuristics requires lower levels of awareness than recalling the heuristics, participants were expected to recognize more heuristics than they could spontaneously recall in Chapter 6.

Furthermore, people's awareness of a heuristic may be closely related to the salience of the heuristics in people's minds. If participants are motivated to make quick and efficient decisions, it is likely that the heuristics that are most salient will be used to judge the energy use of the appliance. This is especially true if participants minimise the number of heuristics that they employ, as postulated by the Categorization by Elimination Model (see next section) (Berretty, Todd, & Martignon, 1999). Therefore, this study may give an indication of the relative influence of the heuristics on the energy judgement.

Considering the large effect sizes of the size heuristic in previous research (r_s =.91 in Baird & Brier, 1981; r = .67 in Schuitema & Steg, 2005), this heuristic was expected to be one of the most salient heuristics and therefore participants were expected to often report using this heuristic. Furthermore, as participants explicitly referred to the usage pattern heuristic in an energy judgement task in previous research (Chisik, 2011), this heuristic was also expected to be frequently identified by participants. Moreover, the heuristics that were reported by participants in the previous study in Chapter 6 were expected to again be frequently recognized (time switched on, heat, function, task size, no. of tasks, speed, activity, perceived energy intensity, task complexity, Wattage, perceived power, task size).

7.1.2 The complexity of an energy judgement

In daily life, people naturally make decisions in a quick and automatic manner as our daily life requires this. This is a very adaptive skill because a full consideration of all the possible outcomes for each decision would not be feasible or desirable as it would result in cognitive overload (Gigerenzer & Goldstein, 1996). The Categorization by Elimination Model (CEM) therefore assumes that people endeavour to only use as many cues as necessary to categorise objects efficiently (Berretty, Todd, & Martignon, 1999). This model suggests that people will minimise the number of heuristics employed to rate the energy consumption of a household device as they are motivated to make quick and efficient decisions. This means that even though there may be numerous different kinds of heuristics that could be used to infer the energy use of an appliance (as found in the study reported in Chapter 6), only a few might be used in each decision making process. If this is the case, people are expected to only select the most salient heuristics to use in their energy judgements, as discussed above.

Knowledge about the number of heuristics that are involved in this decision making process and the consistency of this number across decision making processes would reveal the complexity of energy judgements and thereby further illuminate the use of these heuristics. Furthermore, if people tend to employ a small number of energy judgement heuristics in each decision, then this would imply that addressing the use of these heuristics (e.g. to improve energy literacy) may be more straightforward compared to when a large number of heuristics tend to be employed or if there is a lot of variation in the complexity across different energy judgements.

To date, no previous research has investigated this level of decision making complexity in energy judgements. Therefore, the current study investigated participants’ perceptions of the complexity of their decision making processes by assesing how many heuristics they report to use in each energy judgement and whether this number is consistent across the energy judgements of different appliances. Based on the CEM, it was expected that only few heuristics would be reported to be used in energy judgements and that this number of heuristics would be consistently small across the energy judgement of different appliances.

7.1.3 Research aims

This study aimed to investigate people’s ability to recognize the use of the energy judgement heuristics to assess the awareness of the use of the heuristics. Moreover, this level of awareness of the heuristics might signal the relative importance of these heuristics in the energy judgement process. It was expected that participants would often report to use the size and usage pattern heuristic in an energy judgement task, followed by the other 12 heuristics that participants reported to have used in the study discussed in Chapter 6. Furthermore, the current study also explored the level of complexity of the decision making process by assessing the number of heuristics that participants report to use during an energy judgement and the consistency of this number across energy judgements. Based on the CEM, it was predicted that participants would consistently report to use few heuristics in their energy estimations.

7.2 Method

An online survey was conducted in which participants performed a series of energy judgements tasks and for each energy judgement, they indicated which of the previously identified heuristics they had used to arrive at their estimate. The frequency of the selection of the heuristics was subjected to a cluster analysis to develop clusters of similarly frequent selected heuristics.

7.2.1 Ethical approval

Approval was granted by the University of Bath Department of Psychology ethics committee, reference number 13-004.

7.2.2 Participants

Because the data for this study was collected through the same survey that was used in the study reported in Chapter 4, the participants were the same for these studies. The sample consisted of 248 participants (M_{age}= 27.33, SD_{age}= 10.69, 69.6% female) who varied in nationalities (67% British, 7% Dutch, 4% Germany and other nationalities) and living arrangements (31% living with friends, 20.2% living on university campus, 19.4% living with a partner). Participants were recruited through online and offline advertising that offered a chance of winning a gift voucher in exchange for their participation or, alternatively, participants could earn course credits with their participation when applicable. No restrictions were imposed on the eligibility of participants except for standard ethical age requirements (min. of 18 years). Data from seven participants was missing and therefore these participants were excluded from the analysis.

7.2.3 Materials and procedure

An online questionnaire was designed that included energy judgement tasks and a self-report measure of the heuristics that were used in these tasks (see Appendix B). The second part of this questionnaire also contained items for the study reported in Chapter 4, but this chapter will only focus on the items relevant for this study. For reach appliance, participants were first asked to rate the energy consumption the household device, considering its energy use for one minute of continuous use. As in the previous study, it was essential that like-for-like comparisons were made, and therefore the one-minute level of measurement was chosen as it was a suitable time period where people could compare the consumption of most household devices. Participants indicated their energy judgement on a seven point Likert scale (1 = *uses very little energy per minute*, 7 = *uses a lot of energy per minute*). The ten devices (fridge freezer, oven, washing machine, mobile phone charger, microwave, lightbulb, hairdryer, kettle, tumble dryer, laptop) were selected to represent common daily household appliances, that together covered a range of energy consumption levels and allowed for different heuristics to be applied to determine their energy consumption (i.e. they varied in size, tasks, speeds with which the device operates etc.). This energy judgement task therefore resulted in separate energy judgements for each appliance which facilitated the evaluation of the use of heuristics for each judgement. This energy judgement task was more appropriate for the research aims of this study compare to the rank-order task that was conducted in the study reported in Chapter 6. Because the rank-order task involves the simultaneous consideration of the energy use of various appliances, this task does not allow for the evaluation of the use of heuristics for each separate energy judgement which would limit the number of heuristics that would be reported in this task. Furthermore, the accuracy of the energy judgement was not of interest in this study and therefore this task did not need to be designed to allow for the assessment of the accuracy of the energy rating. Hence, the energy judgement task only served to prompt the use of energy judgement heuristics.

Each energy judgement task was followed up with a question asking participants to report on the heuristics they had used in the energy estimation of the device just considered (see Figure 15). Specifically, participants were asked how they had made the energy judgement and the heuristics identified in Chapter 6 were presented (e.g. "*What kind of things did you consider to determine the energy use of the fridge-freezer?*"). The data collection of the study in Chapter 6 was conducted in two phases, and at the time of the data collection for the current study, the second phase of data collection for the previous study had not yet been completed. The vast majority of the heuristics identified in the second round of data collection for the study reported in Chapter 6 matched the heuristics that were observed in the first round of data collection for this study. However, a few new heuristics arose from the additional data, and these were therefore not included in the current study. Furthermore, the (sub)themes have since been refined and restructured, and therefore, the survey in this study included 30 heuristics that were presented under eight themes instead of the 28 heuristics that were organised under nine themes in Chapter 6.

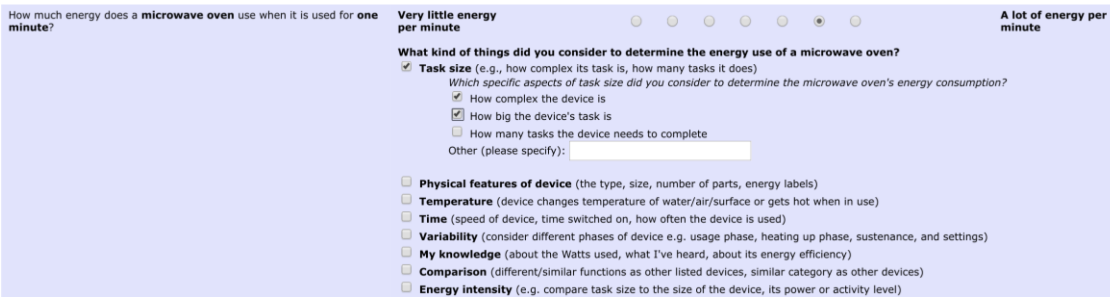

Figure 15: Screenshot of an energy judgement task in the survey and the presentation of the energy judgement heuristics

To reduce the information overload in the survey, the eight heuristic themes that were created in the last study were presented with keywords of the relevant heuristics in brackets (e.g. "*Task size* (e.g. *How complex its task is, how many tasks it does*"), see Figure 15). The heuristic themes and sub-themes were reworded where necessary to ensure that the themes were easy to comprehend. When the heuristic theme was selected, the specific heuristics of the respective theme would then appear. Participants were requested to indicate which of these heuristics they had used when judging the energy consumption of the specific appliance (e.g. "*Which specific aspect of task size did you consider to determine the microwave oven's energy consumption*?"). No restrictions were imposed regarding the number of heuristic that could be selected. This procedure was repeated until all ten devices were rated and the respective heuristics were selected for each energy judgement.

Participants also had the option to provide an alternative heuristic when the presented heuristics did not explain their method of their energy judgement. The alternative heuristics that the participants provided were examined, and the majority of the responses could be classified into the existing heuristic categories, suggesting that the categories provided to the participants covered most of the participants' self-reported heuristics. However, a couple of statements could not be classified into the existing heuristics categories. That is, three alternative heuristics were suggested by the participants: settings (referring to a washing machine: "*We use a low temperature programme*"; note that this heuristic was reported in the previous chapter as it was identified in the analysis of the second phase of data-collection) age of device ("*Mine is new and has good energy rating*") and meter ("*I can see it using a lot of electricity on my meter when I use it*"). The fact that more heuristics were uncovered in this study suggests that the list of heuristics developed in Chapter 6 was not exhaustive. However, it is likely that the addition of these three heuristics may still not complete this list and that many more attributes of an appliance can be used in an energy judgement. Therefore, and to ensure that each heuristic had an equal chance to be selected by the participants, the alternative heuristics were not included in the analysis. They are noted here for interest, and as a reminder that the studies here do not claim to provide a definitive list of all the heuristics a person might use to judge energy consumption.

The frequency with which each heuristic was selected by the participants was not taken to be an indication of the true use of the heuristics because it is unlikely that people are able to accurately report the use of the heuristics (Chaiken, 1980) and might therefore devise the heuristics after they have estimated the energy consumption. Instead, this measure was to reflect participants' ability to recognise their use of the energy judgement heuristic. The recognition of a heuristic was taken to imply participants' awareness of the use of the energy judgement heuristic, because awareness is a requirement for the recognition of the energy judgement heuristic. Moreover, the relative frequency with which each heuristic was selected was assumed to reflect participants' relative awareness of the use of the energy judgement heuristic. This means that participants were assumed to be more aware of heuristics that were more frequently selected compared to heuristics that were not often selected.

7.2.4 Data analysis

The aim of the data analysis was to uncover patterns in how often the heuristics were selected. Specifically, the heuristics that were recognised by the participants as playing a role in their decision making process were identified, and the relative awareness of these heuristics was investigated. As participants were expected to be more aware of the more frequently selected heuristics, the heuristics needed to be categorised in terms of the frequency with which they were selected by the participants. Moreover, the difference in the frequencies with which the heuristics were chosen were of specific interest, and therefore the analysis was performed on the total frequencies of the selection of each heuristic. This thereby factored out the variability between participants and across devices. Only the selection of the specific heuristics was analysed in this study, as the heuristic themes were merely included to organise the heuristics, and their selection was not expected to be informative.

The analysis needed to produce at least three groups of heuristics to identify: 1) the most frequently selected heuristics of which participants were therefore highly aware; 2) the heuristics that had been recognised and of which participants were therefore aware; and 3) the heuristics that were not recognised and of which participants are therefore not aware. One could argue that two groups would suffice to reflect the heuristics that participants reported to have used and which they did not perceive to have used. However, this would not provide any information on the relative awareness of the different heuristics, and therefore a minimum of three groups was required in this study.

7.2.4.1 Cluster analysis

To produce these groups of heuristics based on the variance in the data rather than using an arbitrary cut-off value introduced by the researcher, cluster analysis was used. Cluster analysis provides a reliable method of classifying the heuristics into groups in terms of the frequency with which they were selected by the participants. This method aims to organise datasets in a way that enhances the ease and efficiency of interpretation by discovering groups or clusters of homogenous observations in the data (Everitt, Landau, & Lees, 2011). The key principle of the method is to define items as similar when they are proximate to one another in the *n*-dimensional space defined by the measurements used in the analysis (Gore, 2000). Items that lie close together in this space get clustered together, indicating they show similarity across the measurements. For the analysis of the current study, this means that heuristics were clustered together when they were similar in the frequency with which they were selected by the participants. The following sections will discuss the justifications for the chosen type of cluster analysis, the method, the linkage rules, the distance measure and how the results of the analysis will be interpreted.

Two types of cluster analysis are predominantly used in psychology*:* hierarchical cluster analysis and optimisation clustering techniques. *Hierarchical cluster analysis* is a data-driven technique that involves a number of steps in which the optimal number of clusters are found, whereas the number of clusters in *optimisation clustering* (a.k.a. *non-hierarchical cluster analysis* or *k-means clustering*) is determined before the analysis, meaning that the data is classified into a specified number of groups (Everitt et al., 2011). Although the analysis aimed to identify at least three groups of heuristics, this study did not require the data to be organised into a fixed number of groups. That is, the analysis could have resulted in as many clusters as appropriate, as long as a minimum of three clusters were found, because there was no hypothesis on the number of clusters that were to be identified. Furthermore, as optimisation clustering does not allow the data to determine the number of clusters, but rather forces the data into a predetermined number of clusters, this method would provide less information of the patterns in the dataset. Therefore, hierarchical cluster analysis was the most appropriate analysis for the current study.

There are two methods with which hierarchical cluster analysis can be applied. First, an agglomerative method can be used, which applies a bottom-up approach by starting with a separate cluster for each variable and successively merging the clusters to end with one cluster that encompasses all variables (Everitt et al., 2011). Alternatively, divisive methods can be employed, which use a top-down approach of starting with one cluster that includes all variables and breaking these down into successively smaller clusters (Everitt et al., 2011). Although literature remains unclear on the differences in solutions between the two methods and when which method should be used (e.g. Gordon, 1987), the agglomerative method is more commonly used (Everitt et al., 2011) and is therefore more widely supported by statistical software, hence the agglomerative method was applied for this analysis.

Linkage rules determine when clusters are sufficiently different from each other to form separate clusters. There are a large number of linkage rules that can be applied to cluster analysis, and therefore this section will only consider the most established ones. The most common approaches include the *single linkage method*, which classifies the most proximate objects together, and the *complete linkage method* which creates clusters based on the objects that are furthest from each other (Anderson, 1973), both methods are illustrated in Figure 16. These approaches are limited in that the complete linkage method is only suitable when the data is expected to consist of naturally distinct chunks, and the single linkage method tends to create long indistinct clusters that does not make it suitable for data that does not have clear clusters (Hill & Lewicki, 2007). Another popular method is Ward's method that aims to minimise the sum of squares of each combination of clusters that can be formed in each stage (Hill & Lewicki, 2007). This method has been found to be sensitive to outliers (Lorr, 1983) and because a graphical inspection of the data suggested the presence of outliers, this method would not be appropriate for this analysis. As it is unknown whether the data will consist of naturally distinct chunks or chain-type clusters, the most appropriate linkage rule that could be applied is the *group average linkage* (also illustrated in Figure 16) that has been found to work well for data that consist of natural 'clumps' as well as data consisting of long chains (Hill & Lewicki, 2007). The group average linkage method is characterised by the average distance between all pairs of objects in the two clusters (Anderson, 1973). This linkage method does not have any admissibility conditions (unlike the other linkage methods) (Everitt et al., 2011) and has been found to be one of the most effective linkage methods (Lorr, 1983).

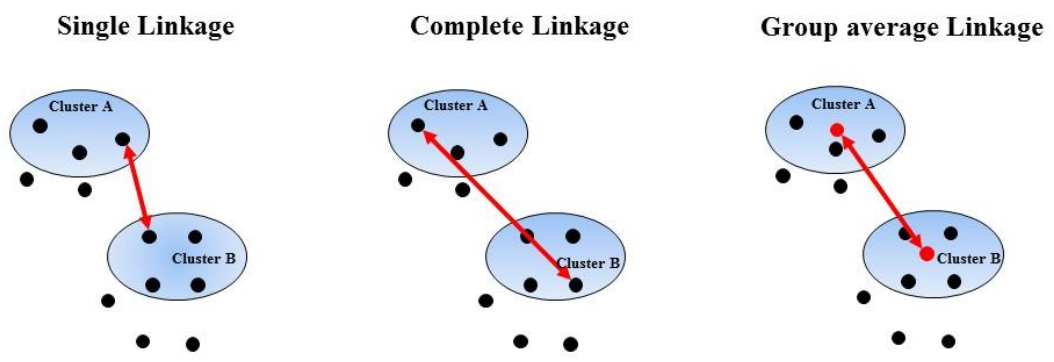

Figure 16: Examples of three inter-cluster linkage methods: single, complete and group average.

The most appropriate distance measure for the cluster analysis was the squared Euclidean distance measure that considers the actual geometric distance in the multidimensional space and is the most commonly used measure in cluster analysis when the data is continuous (Hill & Lewicki, 2007). That means that if the data is plotted on a graph, the geometric distance between these objects are taken as the distance measure. The disadvantage of this measure is that it is strongly affected by differences in scale among the dimensions (Hill & Lewicki, 2007). However, as the scale used in the current study was consistent across items (because the value for each heuristic represent its frequency of selection), this does not pose a concern for this analysis. Moreover, the squared Euclidean distance measure was chosen as opposed to the regular Euclidean distance measure as it progressively emphasizes observations that are further apart, which ensures that separate clusters will be formed for objects that are more distant from each other (Hill & Lewicki, 2007).

The hierarchical cluster analysis generated an agglomeration schedule, which was used to decide on the optimal number of clusters. The agglomeration schedule provides a solution for every possible number of clusters by progressively merging more clusters together. The schedule reports the coefficient values for each cluster solution, which reflects the squared Euclidean distance between the two cases that are combined (Gore, 2000). A large change in coefficients when moving from one stage to the next can be interpreted as a demarcation point, indicating that the optimal number of clusters has been reached. Merging more clusters together after this point results in considerably less homogenous groups, as indicated by the coefficients, which rapidly become larger after this point (Gore, 2000). However, various gaps may be identified, and the gap between coefficients will naturally be largest when moving down in the agglomeration schedule (resulting in fewer clusters). Therefore, where appropriate, the ratio of the coefficients that border the gap was computed. The coefficients that created the largest ratio highlight the most abrupt change in coefficients and therefore indicate the ultimate demarcation point, meaning that the optimal number of clusters has been reached in the stage before this point.

Furthermore, the dendrogram can also be consulted to decide on the optimal solution (Everitt et al., 2011). The dendrogram is a visual representation of the clusters in which the horizontal axis reflects the linkage distance and thereby facilitates a clear interpretation of the optimal cluster solution. The longer the horizontal distance between two bifurcations, the greater the distance between the clusters produced by those bifurcations. By cutting branches off the dendrogram where the linkage distance is high, the optimal number of clusters can be found. Logically, the linkage distance coincides with the coefficients in the agglomeration schedule.

Although the dispersion between the coefficients at the different stages in the agglomeration schedule and the linkage distances in the dendrogram was key in determining the optimal number of clusters, it was important that also the research aims of the current study were considered in this judgement. That is, because the aim of this study was to identify of which heuristics participants were most aware, of which heuristics participants were aware at all and of which heuristics participants were not aware, it was crucial that at least three clusters were produced in which heuristics were grouped accordingly. Moreover, it would not have been informative to have a cluster solution in which too many clusters were produced, meaning that the heuristics would have been spread thinly over a large number of clusters that would prevent a clear interpretation of the results. Accordingly, it was important that a balance between a parsimonious solution and a rich description of the data was found in the cluster solution (Everitt et al., 2011).

Finally, to assess the complexity of the decision making process, the mean number of heuristics that the participants reported using in each decision was examined. In other words, the mean number of heuristics reported for each decision, collapsing across participants and appliances, reflected the complexity of the decision making process. Furthermore, the standard deviation of the mean number of heuristics used in each decision was inspected to evaluate the consistency of the decision making complexity.

7.3 Results

The following sections will first report on the cluster analysis on the frequencies of the heuristics, followed by the analysis on the complexity of the decisions.

7.3.1 Awareness of energy judgement heuristics

As discussed above, a hierarchical cluster analysis was performed on the total frequencies of all 30 heuristics to assess which were endorsed with similar frequencies. The agglomeration schedule (see Table 10) showed a large change in coefficients in three places: between stage 26 and 27 (10,081.50 difference), between stages 27 and 28 (36,999.72 difference), and between stages 28 and 29 (184,128.24 difference), which supported four, three, or two clusters respectively. The ratio of the coefficients were 2.11, 2.93 and 4.3 respectively, suggesting the most abrupt change in coefficient between phase 28 and 29, which would suggest only 2 clusters.

The dendrogram (see Figure 17), clearly displayed these cluster solutions and a quick visual inspection of the graph might suggest that the two cluster solution was best supported due to the largest linkage distance, similar to the agglomeration schedule. However, the two cluster solution grouped two heuristics into one cluster and 28 heuristics into the other cluster, meaning that this solution only distinguished frequently selected heuristics from not frequently selected heuristics. This solution would therefore not have satisfied the research aim, as it did not provide much information about the data, by failing to divide the heuristics into different degrees of frequencies with which the heuristics were selected.

The three cluster solution was more informative as the heuristics were slightly more spread among the clusters, but only when the four cluster solution was inspected, a heuristic with an extremely low count was identified. As these four clusters were therefore more likely to give a rich description of the dataset, this solution was found to satisfy the aim of this study best. This solution was therefore taken forward in the analysis, however, it needs to be noted that this was not the optimal solution according to the agglomeration schedule and dendrogram, and this needs to be taken into account when interpreting the findings.

Table 10: Agglomeration schedule of the cluster analysis on the frequency of the selection of the heuristics

Stage	**Cluster combined**		**Total no. of clusters**	**Coefficients**	**Change**
	Cluster 1	Cluster 2			
1	4	18	29	1.00	
2	20	30	28	4.00	3.00
3	23	28	27	4.00	0.00
4	19	22	26	4.00	0.00
5	14	17	25	4.00	0.00
6	15	24	24	9.00	5.00
7	16	20	23	10.00	1.00
8	3	9	22	25.00	15.00
9	3	5	21	62.50	37.50
10	1	29	20	81.00	18.50
11	14	25	19	101.00	20.00
12	6	19	18	101.00	0.00
13	8	12	17	121.00	20.00
14	7	27	16	169.00	48.00
15	13	16	15	171.67	2.67
16	4	21	14	210.50	38.83
17	14	15	13	216.50	6.00
18	2	11	12	324.00	107.50
19	3	23	11	378.67	54.67
20	3	13	10	906.35	527.68
21	6	14	9	1052.73	146.38
22	7	10	8	1302.50	249.77
23	2	7	7	3341.33	2,038.83
24	3	4	6	3974.26	632.93
25	3	6	5	7258.69	3,284.43
26	1	2	4	9108.90	1,850.21
27	3	26	3	19190.40	10,081.50
28	1	3	2	56190.12	36,999.72
29	1	8	1	240318.36	184,128.24

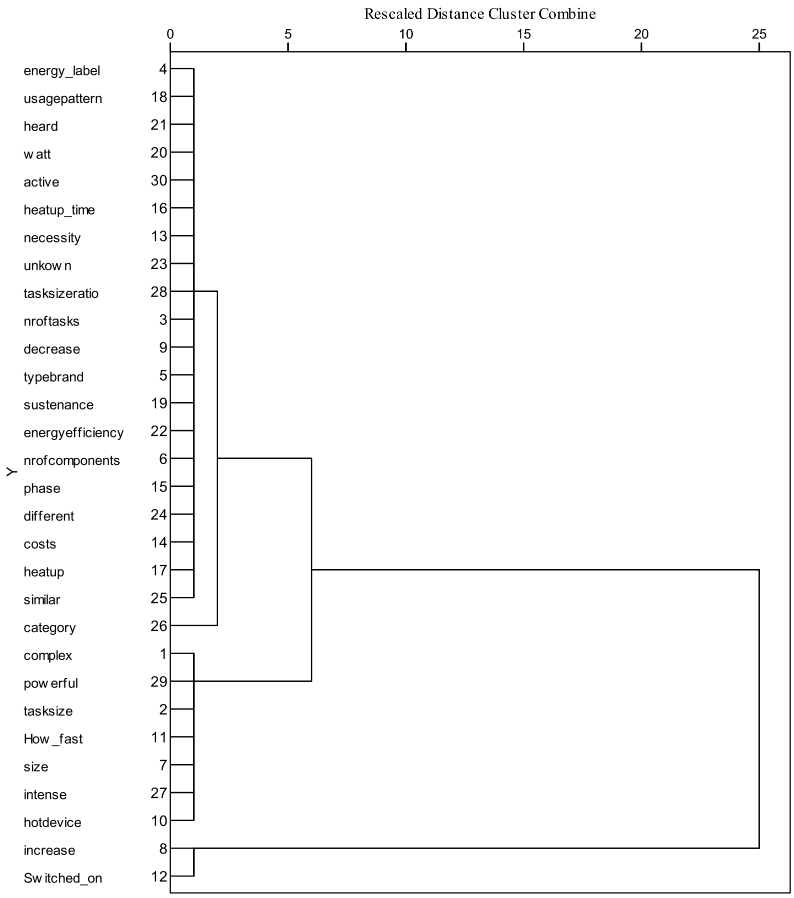

Figure 17: Dendrogram of the cluster analysis on the frequency of the selection of the heuristics

The four clusters can be interpreted as a cluster of the most frequent reported heuristics, the moderately frequent reported heuristics, infrequent reported heuristics and least frequent reported heuristics (See Table 11). The most frequent reported heuristics cluster consisted of the heat heuristic (selected 689 times, 9.69%) and the time switched on heuristic (selected 677 times, 9.53%) which together accounted for 19.22% of the selected heuristics. Next, the moderately frequent cluster included seven heuristics among which the speed heuristic (selected 442 times, 6.22%) and task complexity heuristic (selected 305 times, 4.29%) and all the heuristics in this cluster together made up 36.91% of the selected heuristics. The cluster that consisted of the infrequent selected heuristics included 20 heuristics among which the received wisdom heuristic (selected 241 times, 3.39%) and function similarity heuristic (selected 84 times, 1.18%). All of the heuristics together in this cluster accounted for 43.49% of the selected heuristics. Finally, the least frequent cluster, which was a single member cluster, consisted of the category heuristic that was only selected 24 times, comprising 0.34% of the selected heuristics.

Table 11: *Frequencies and percentages of the selection of heuristics per cluster*

Cluster	Heuristic theme	Frequency	Percentage
1: Most frequent	Heat	689	9.69
	Time switched on	677	9.53
2: Moderately frequent	Speed	442	6.22
	Task size	424	5.97
	Intensity	397	5.59
	Size	385	5.42
	Device getting hot	442	5.00
	Perceived power	314	4.42
	Task complexity	305	4.29
3: Infrequent	Received wisdom	241	3.39
	Energy label	228	3.21
	Usage pattern	227	3.19
	Necessity	196	2.76
	Watt	185	2.60
	Activity	183	2.57
	Speed of heating up	181	2.55
	Cold	171	2.41
	Number of tasks	166	2.34
	Type/brand	161	2.27
	Unknown	148	2.08
	Task/size ratio	146	2.05
	Number of components	134	1.89
	Sustenance	125	1.76
	Energy efficiency	123	1.73
	Which phase it is used in	106	1.49
	Function dissimilarity	102	1.43
	Heating up	95	1.34
	Financial costs	93	1.31
	Function similarity	84	1.18
4: Least frequent	Category	24	0.34

7.3.2 Complexity of decision making

As described above, the complexity of the decision making process was measured in terms of the number of heuristics that participants reported considering when rating each device. On average, participants reported using 2.87 out of 30 heuristics for each decision (i.e. rating each device). Nevertheless, the number of heuristics that participants reported to employ in each decisions strongly varied across participants and appliances (*SD*=2.91).

7.4 Discussion

This study aimed to quantify the relative awareness of the energy judgement heuristics found in the study reported in Chapter 6. Moreover, the decision making complexity was explored by examining the number of heuristics that were reported to be used during an energy judgement as well as the consistency of this number across decisions.

7.4.1 The awareness of energy judgement heuristics

The findings of the current study suggest that people recognised more types of heuristic than they can spontaneously report, as all but one heuristic (see below) was recognised in this study whereas only 14 were recalled unprompted by participants in the previous study. This is not surprising as the listing of the energy judgement heuristics facilitated introspection and required lower levels of awareness of the heuristics compared to the recall method used in Chapter 6. This finding therefore confirms that people have different levels of awareness of the energy judgement heuristics they employ. That is, participants have more awareness of the spontaneously recalled heuristics whereas the recognition of the energy judgement heuristics requires lower levels of awareness. Moreover, because almost all heuristics have been recognised to some extent, the findings of this study can be taken as a validation of the energy judgement heuristics that were identified – using a different sample – in the previous study. That is, the participants here were at least somewhat aware of the heuristics identified from the earlier group of participants, implying that these heuristics are truly used in energy judgements and were not a mere interpretation of the researcher in the previous study. Furthermore, the energy judgement task used in the current study differed from the energy judgement task that was employed in the study discussed in Chapter 6, in that the current method did not involve direct comparisons between appliances. Because the participants in the current study endorsed the energy judgement heuristics found in the previous study, this suggests that these heuristics are independent of the type of energy judgement task.

The cluster analysis on the frequency of the selection of the heuristics resulted in four clusters. The cluster that reflected the most frequently chosen heuristics consisted of the heat and time switched on heuristics. First, this means that participants frequently agreed that they considered whether the device increased the temperature of an element to judge the energy use of an appliance. The discussions reported in Chapter 6 showed that with this heuristic, appliances that produce more heat, were perceived to consume more energy compared to appliances that produce no or less heat. Second, participants frequently recognised the time switched on heuristic in their decision making process, in which participants tended to rate devices that are switched on for a long time as using less energy per minute than devices that are not, as was observed in the study discussed in Chapter 6. The selection of these two heuristics made up almost 20% of the total selections of the heuristics, showing that participants were strongly aware of the use of these heuristics and likely perceived them to be important in their energy judgements. These findings, and the ease with which heat and time switched on heuristics were identified in Chapter 6, all converge to provide strong support for the idea that people use these two strategies extensively when judging device energy consumption.

The second cluster, making up the moderately frequent selected heuristics, included speed, task size, intensity, size, device getting hot, perceived power and task complexity. As expected, all of these heuristics (except for the device getting hot heuristic) were reported by participants when they were asked to reflect on their strategies in the study reported in Chapter 6. Therefore, similar to the heuristics above, these may represent heuristics that people truly use or, at least, of which they are strongly aware.

Most of the other heuristics reported by participants in Chapter 6 either fell into the frequently selected cluster or the top half of the infrequently selected cluster. This means that most of the explicitly reported heuristics in that study were also frequently recognized by participants in the current study. However, the task/size ratio heuristic and the function similarity heuristic, which participants spontaneously recalled using in the previous study, were only selected 146 times (making up 2.05% of the selections) and 84 times (1.18%) in the current study, suggesting lower levels of awareness of these heuristics. Although the findings in Chapter 6 may suggest high levels of awareness of these heuristics and the current study suggests low levels of awareness, these heuristics *were* validated by participants in this study. Moreover, considering the quantitative methods, and thereby larger sample size in the current study, it is likely that the findings of this study are more reliable and therefore people are more likely to have low levels of awareness of these heuristics.

There was one heuristic that clearly stood out in terms of the low frequency with which it was selected. This was the category heuristic, in which participants perceive appliances that are semantically related with each other as consuming similar levels of energy, which was only selected 24 for times and thereby only accounted for 0.34% of the selected heuristics. Interestingly, in Chapter 6, this was the second most frequently observed heuristic, but was not reported by participants at all. This clearly suggests that participants were unaware that they used this heuristic, as the awareness of the heuristic is a requirement for participants to be able to indicate it was used. In other words, participants may not have recognised the heuristic when it was presented because they were unaware that they used it in the first place. Therefore, this may be a key heuristic that is used without much conscious thought or intention. Furthermore, this might explain why the heuristic was often observed to be used during the energy judgement task in the previous study, but was not often reported by participants when they were asked about their thought process in the same study, and was not frequently recognised in the current study.

Alternatively, it is possible that participants hardly selected this heuristic because they did not understand the way it was conveyed. In the survey, the heuristic was phrased as "*rate items that can be classified in one category similarly*". Perhaps the word 'category' was perceived as ambiguous by participants, which prevented them from selecting it. The infrequent selection of this heuristic may also have been due to the lack of comparisons across appliances in the energy judgement task in this study. The application of the category heuristic requires several appliances to be compared on energy consumption to classify them into a similar energy consuming category. Because participants in this study did not rank-order the appliances, nor rate the energy use in comparison to a reference point appliance, the participants may have only considered the energy use of the target appliance in their judgement. This would suggest that the use of the category heuristic as found in the study in Chapter 6 may have been inherent to the energy judgement task. However, it was still possible for participants to use this heuristic, as they may have consulted a previous energy judgement of an appliance that could be classified into the same category. Finally, the infrequent selection may also indicate that people do not use this heuristic, and the identification of the heuristic in Chapter 6 was a misinterpretation of the researcher. That is, this heuristic was developed as participants were often observed to group devices together that could be said to belong to the same semantic category (e.g. a washing machine with a tumble dryer or an oven with a microwave). However, this heuristic was not explicitly discussed by participants in the previous study, and therefore the use of this heuristic may have been a misinterpretation.

Previous research has uncovered the size and usage pattern heuristics, and these were expected to emerge as being perceived as important heuristics in the decision making process. Although the size heuristic was included in the moderately frequent cluster, it was only the 6th most frequently reported heuristic, making up 5.42% of those selected. These results seem inconsistent with previous research, in which strong correlations were found between the rating of the energy consumption and the size of the device, such that people generally assume that large appliances use a lot of energy (Baird & Brier, 1981; Schuitema & Steg, 2005). This discrepancy therefore suggests that people might not be aware of the strong influence of the size heuristic in their decision making process meaning that they underestimate the influence of the size heuristic on their energy judgement.

Moreover, it is also possible that the size heuristic is not one of the most influential heuristics in energy judgements. That is, the previous studies have not assessed the use of the heuristics that were most frequently reported to be used in the current study (e.g. heat and time switched on) and therefore previous research has not compared the influence of the size heuristic with the heuristics that were most often reported in the current study. This means that the size heuristic may play an important role in energy estimations, but other heuristics may play an even larger role in this decision making process. Alternatively, the discrepancy between previous research and the current study may be attributed to differences in methodology as the energy judgement task in both of these previous studies required participants to rate the energy use of appliances in comparison to other appliances, whereas a direct comparison of appliances was not necessarily required in the task in the current study. It is therefore possible that the size heuristic is more likely to be used in energy judgement tasks that involve direct comparisons of appliances, than tasks that do not require this comparison.

The other heuristic that has been identified in previous research is the usage pattern heuristic, which was therefore also anticipated to be frequently recognised by participants in this study. In the current study, this heuristic was categorised in the infrequent cluster as it only made up 3.19% of the selected heuristics. This discrepancy between previous research and the current study is particularly striking as the use of the heuristic was not inferred retrospectively in previous research (as was the case for the size heuristics in previous studies), but participants explicitly referred to the usage pattern of the appliance in the study by Chisik (2011). Nevertheless, one major difference between Chisik's study and the two studies in this thesis is that participants in the current and previous study considered the energy consumption for one minute of use, whereas such limitations were not imposed in the study by Chisik. This is very likely to have explained the low occurrence of the selection of this heuristic in the current study, as participants were effectively instructed not to take the usage pattern of the appliance into account. The low occurrence of the usage pattern heuristic in the current study perhaps merely demonstrates that participants have followed these instructions (which is itself a useful check on the procedure here). This discrepancy therefore suggests that the usage pattern heuristic tends to only be used when the total amount of energy consumption of an appliance is estimated over a long period, such as a year.

7.4.2 Findings on the complexity of the decision making process

On average, participants reported considering almost three heuristics per decision. This number of heuristics could be taken as evidence that participants tended to engage in a fairly quick and efficient decision making process. These findings may therefore be in line with the Categorization by Elimination Model that predicts that people will minimise the number of attributes (and thereby heuristics) of an object that they consider when making a judgement about the object (Berretty et al., 1999).

However, taking three different types of heuristic rules into account when judging the energy use of an appliance may not be that straightforward. That is, for each heuristic, one needs to rate the appliance on the heuristic attribute, define the relation between the heuristic attribute and the energy consumption, and then apply this rule to arrive at the energy estimate. This may be a complicated process, because not only would people have to go through this process for all three heuristics, they would also need to weigh the importance (and therefore application) of the heuristics relative to each other as it is likely that the heuristics will differ in their perceived validity and applicability. Instead, it would be much simpler to only use one heuristic that is perceived to be relevant for the device and infer its energy consumption accordingly. The fact that participants reported using several heuristics for each decision may indicate that participants were uncertain of the energy consumption and were compensating for this uncertainty by using a range of heuristics. Furthermore, this finding also suggests that participants expect that a single heuristic will not result in a valid energy estimation on its own.

The standard deviation of the number of heuristics that participants reported to have used was rather high, suggesting that the decision making complexity strongly varied across appliances and participants. Perhaps participants who felt less confident about the energy consumption of the appliances may have indicated using more heuristics compared to participants who felt more capable to complete this task. More heuristics may have been used in energy estimates for devices of which the energy use is less well-known (such as a desktop computer) compared to appliances of which the energy use is quite well-known (e.g. microwave). Similarly, more heuristics may have been employed in the energy judgements for devices for which no salient heuristic may have applied (e.g. DVD player) compared to devices for which salient heuristics, such as the heat heuristic, clearly applied (e.g. oven).

7.4.3 Methodological evaluations

Although the findings of this study illuminate people's awareness of heuristics in energy judgements, these findings need to be interpreted in light of the strengths and limitations of the methods that were used in this study.

First, the use of the heuristics was measured with a self-report method. This measure allowed for the assessment of participants' perceptions of the use of the prompted heuristics, and thereby their ability to recognise these heuristics. However, a number of issues can arise when using self-report, such as the consistency motive (Heider, 1958) which implies that participants attempt to maintain consistency among their responses (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). In this study, this could mean that once participants had entered their response for the first item (i.e. the first device that they were asked to rate), they may have had the tendency to select the same heuristics for each subsequent device and not inspect the alternative heuristics that were presented even though other heuristics were applied for the rating of different devices. This bias would have resulted in a limited variety of heuristics being reported. If the appliance that was first presented indeed determined which heuristics tended to be reported by participants in the subsequent energy judgements, it may have been better to have displayed these appliances in random order. However, because all of the listed heuristics were selected several times, this suggests that this bias may not have been too prevalent, although this does not reflect within participant variations. Moreover, if this bias resulted in less variance in the reported heuristics, the relative frequency of the selection of the heuristics would still have reflected the relative awareness of the heuristics, and therefore this does not impose a threat to the validity of the measure.

One could also argue that the frequency with which heuristics were endorsed in the survey may not truly represent the awareness of the use of these heuristics. That is, it is possible that participants may have simply selected the heuristics that they perceived to be plausible strategies to judge the energy use of the appliance, rather than that these heuristics were actually recognised in their decision making process. In other words, the selection may not have genuinely reflected their energy judgement, but rather the perceived validity of the heuristics after the energy judgement was established. However, if that was the case, the relative frequency with which the heuristics were selected would still be meaningful as it is likely to reflect the likelihood with which they would be used. That is, heuristics that are perceived as more useful to judge the energy consumption of the appliance with, can be expected to be more likely to be employed in energy judgements.

In a similar way, this measure may not necessarily reflect the true number of heuristics that were used. Participants may not have accurate insights in the use of the heuristics because some may be used unconsciously and unintentionally. That is because the previous section suggested that participants may not be strongly aware of the use of all energy judgement heuristics. Moreover, it is possible that participants may not have been sufficiently motivated to list all the heuristics that they considered during their energy judgement and may have underreported the number of heuristics that they thought they had employed. If this was indeed the case, the true energy judgement may therefore have been even more complex than found in this study. Nevertheless, the findings in this study reveal that participants are aware of using almost three heuristics in each energy judgement, which does suggest that people tend to use multiple heuristics in their energy judgements.

Moreover, the measure of the decision making complexity may have lacked external validity. This means that the measure may not have assessed how people think about the energy consumption in their household in their daily lives. It is likely that the explicit nature of this study motivated participants to think about the energy consumption of the devices in a more elaborate manner than they would when they interact with their household devices in their daily lives, which might involve more automatic thought processes. However, householders can be expected to engage in such elaborate thought processes when investing in their domestic appliances, and therefore the measure in this study is likely to be relevant to such decision making processes.

Furthermore, care was taken that the appliances that were included allowed all of the heuristics to be applied to determine their energy consumption (i.e. they varied in sizes, tasks, speeds with which the device operates etc.). However, it is likely that the heuristics significantly differed in their applicability when rating the different household devices. For example, the size heuristic can be applied to rate the energy consumption of almost any household device, whereas the 'cold' heuristic could only apply to a limited number of appliances such as freezers. Nevertheless, the latter heuristic may still be very influential in the decision making process when rating certain devices, and therefore its importance should not be disregarded due to its low frequency.

The heuristic groups that were identified in the cluster analysis were quite ambiguous as small changes in the frequencies, or number of heuristics that were included, could have had an effect on the clusters that were formed. Moreover, the judgement of the optimal number of clusters was rather subjective, as various factors (e.g. the squared Euclidean distance coefficients, the linkage distances on the dendrogram and the research aims) were taken into account and weighted to arrive at the most appropriate number of clusters in the dataset. The heuristics were merely clusters to organise the heuristics by frequency, and it is therefore important that the clusters are not interpreted as fixed and distinct categories but the frequencies of each heuristic are taken into account.

A final concern about the methodology of this study relates to the way the heuristics were presented in the survey. The large number of heuristics that were observed in the previous study made it difficult to present all of the heuristics simultaneously without overwhelming the participants with the number of options they could select. Therefore, the heuristic themes were chosen to be directly presented, and the individual heuristics only appeared when the associated heuristic theme was selected. This implied that participants would not see the individual heuristics of the heuristic themes that they did not select, meaning that they could have missed heuristics. To reduce the chance of participants missing heuristics, the individual heuristics were summarised in brackets behind the heuristic theme names. Furthermore, participants were given the option to enter their own responses when the response options did not correspond to their thought processes. As discussed in section 7.2.3, most of the responses that were entered in this way could be classified into the existing heuristics that were presented in other heuristic themes. This option therefore seemed to have resolved part of this issue; however, heuristics that participants did not think of in the first place or were overlooked in the heuristics list were still not reported through this route.

7.4.4 Implications and future research directions

The findings of this study showed that participants were aware of most of the heuristics that were identified in Chapter 6, which may indicate that these energy judgements tend to be used in a conscious and deliberate way. That is, people are not good at reporting the use of heuristics that are employed unconsciously (Chaiken, 1987; Chaiken, 1980), and therefore these findings suggest the deliberate use of the energy judgement heuristics, especially the frequently recognised heuristics. Such heuristics may therefore be used in a similar way as the recognition heuristic discussed in that is also used in a deliberate way to make inferences of unknown attributes (Gigerenzer & Goldstein, 1996). Future research could therefore investigate the deliberateness with which the energy judgement heuristics are used.

The results of the current chapter indicate which heuristics might be most salient in people's minds and may therefore be most influential in an energy judgement. Specifically, it was found that the most commonly reported heuristics were the heat and the time switched on heuristics. These findings could have real-world applications as it is likely that the heat heuristic will result in more accurate energy judgements compared to the time switched on heuristic and therefore efforts to improve device energy literacy may need to focus on promoting the use of the heat heuristic and dissuading people from employing the time switched on heuristic. The study reported in the next chapter will therefore investigate if the use of these two heuristics can be changed, and if this in turn can improve people's energy literacy and stimulate energy conservation.

7.4.5 Conclusion

This study aimed to quantify people's awareness of energy judgement heuristics and explore the decision making complexity of energy judgements. Participants showed that they were aware of most of the heuristics that were identified in Chapter 6, and were most aware they used the heat and time switched on heuristics. However, the heuristic that was most frequently observed to be used in the previous study, the category heuristic, was least recognized by participants. These results therefore illustrated how people may be more strongly aware of the use of some energy judgement heuristics and rather unaware of the use of others. Furthermore, participants were found to report to use almost three heuristics per energy judgement, and this number varied widely across participants and appliances, suggesting that this decision making process is fairly complex.

Chapter 8: Improving Energy Literacy by Addressing the use of Energy Judgement heuristics

This final study investigated whether the use of the heuristics previously identified could be influenced by providing information on the validity of these heuristics to improve energy literacy and stimulate energy saving behaviour. Participants (N=108) were randomly assigned to a condition which informed them about a valid heuristic (the heat heuristic), about both a valid and an invalid heuristic (the heat and time switched on heuristics) or a control condition without information provision. Results showed no effect of condition on energy literacy or energy saving, which may have been due to cross-contamination across conditions. However, participants were found to have improved their device energy literacy after the intervention, and this effect was mediated by the increased use of the heat heuristic. This study therefore shows that the use of heuristics can be changed, and that this in turn improves energy literacy. However, this improved energy literacy did not translate into energy saving behaviour – possibly, in this case, due to methodological issues.

8.1 Introduction

The study discussed in Chapter 6 uncovered a wealth of energy judgement heuristics, and the study discussed in Chapter 7 demonstrated that people are most aware of the use of the heat and time switched on heuristics. Although the heat heuristic is likely to benefit the accuracy of energy estimates, the time switched on heuristic is unlikely to do so. Considering the impact of these heuristics on the accuracy of energy judgements, addressing the use of these heuristics may provide an opportunity to improve people's energy literacy. Indeed, participants in the study reported in Chapter 6 expressed to be interested to learn about the validity of energy judgement heuristics and were found to be willing to change their perception and use of these heuristics. If information provision on the validity of energy judgement heuristics can change the use of these heuristics, and thereby improve people's energy literacy, this could empower households to save energy. No research has previously tested this hypothesis, despite the clear relevance for campaigns that aim to stimulate domestic energy conservation. Therefore, this study aimed to test if informing people about the validity of energy judgement heuristics can improve energy literacy and thereby stimulate energy conservation.

Behaviour change campaigns in the health domain have been found to be most effective when fear appeals, which tend to emphasise the negative consequences of a particular behaviour, are combined with information that enhances efficacy (Witte & Allen, 2000). This has been explained with the Extension Parallel Process Model (Witte, 1992) which postulates that the evaluation of the appeal elicits two separate appraisals. First, receivers appraise the threat of the issue conveyed in the message and the relevance to them. If the threat is perceived as strong enough, receivers are motivated to engage in the second appraisal which is the evaluation of the efficacy of the recommended response (Witte, 1992). This means that if the message on the harmful behaviour is not perceived to be relevant, the individual will not perceive any need to change their behaviour.

A similar kind of reasoning may apply to this study. Simultaneously giving people information about an invalid and valid heuristic may result in the largest change in the use of the heuristics. That is, the information on the invalid heuristic may signal a need to change the way energy is estimated and the information on the valid heuristic may increase the individual's efficacy to better estimate the energy use, by replacing the use of the invalid heuristic with a valid heuristic. Therefore, information on the negative impact of an invalid energy judgement heuristic is expected to be most effective when combined with a message conveying which alternative heuristic could be used instead to better estimate the energy use.

Furthermore, the previous chapters have focused on energy literacy in relation to the knowledge of the energy use of the household devices. However, another type of energy literacy may be even more closely related to energy saving behaviour: the understanding of the impact of energy saving activities. When individuals are motivated to save energy, knowing the impact of household activities is vital to optimise efficient energy saving behaviour. Therefore, the study in this chapter did not only investigate the effect of information provision on device energy literacy, but also explored its effect on activity energy literacy by assessing how well participants can estimate the relative impact of energy saving activities in the household.

This focus on *activities* is different to the focus on *appliances*, which has been the main topic of energy literacy research in the past (Attari, DeKay, Davidson, & de Bruin, 2011; Baird & Brier, 1981; Chisik, 2011; Pierce & Paulos, 2010; Schuitema & Steg, 2005). Few studies have explored how well participants can estimate the energy savings (in terms of financial savings or kWh) of specific energy conservation behaviours in the household. Exceptions include research which assessed financial estimates of salient energy saving activities (Kempton et al., 1985). Findings suggested that participants tended to vastly overestimate the energy savings of curtailment strategies. This was confirmed in more recent research by Attari and colleagues, in which participants mistakenly over-focused and overestimated the impact of curtailment strategies compared to efficiency strategies (Attari, Dekay, Davidson, Bruine, & Bruin, 2010). This study also found that participants vastly underestimate large energy savings and slightly overestimate the energy savings from low energy saving activities, although this effect may be attributed to the study's methodology which was susceptible to the anchoring and adjustment heuristic, as discussed in Chapter 5 (Frederick et al., 2011). Moreover, these misperceptions may also be household-domain specific, as people tend to especially misperceive the energy use of cooking activities (Bodzin, 2012; DeWaters & Powers, 2008; Gatersleben et al., 2002). This research therefore further suggests a lack of awareness of the energy consumption of domestic energy saving activities.

None of these studies have explored the role of energy judgement heuristics in relation to activity energy literacy. It is likely that these heuristics are also employed to estimate the relative impact of energy saving activities, considering that the interaction with appliances are often central in energy saving behaviour. Therefore, this research investigated whether the use of energy judgement heuristics can be changed and if this change can improve not only device energy literacy but also activity energy literacy. Moreover, this study aimed to further extend previous research on activity energy literacy by also investigating if this energy literacy influences the selection of energy saving behaviour. That is, this study also explored if improving knowledge about the impact of energy saving behaviours resulted in the engagement in more impactful energy saving activities

8.1.1 Overview of the current study

The current study investigated if energy literacy and energy conservation can be aided by providing information on the validity of energy judgement heuristics. The heuristics that participants were found to be most aware of in the previous study will be addressed, as it was expected that the use of heuristics of which people are strongly aware of are easier to change compared to heuristics that people are less aware of, because people might be less likely to control the use of heuristics that are used without awareness. Specifically, the heuristics addressed in this study were the heat heuristic, in which the extent to which a device increases the temperature of air or water is considered when judging the energy use, and the time switched on heuristic, in which the length of time a device is generally switched on for is used as an indicator of its energy use. The selection of these two heuristics was informed by the advice of energy experts that the heat heuristic should lead to valid estimations of energy use whereas the time switched on heuristic was based on a range of (potentially invalid) assumptions (see discussion in Chapter 7).

This study included three conditions that differed in information provision. One condition included information on a valid energy estimating heuristic (the heat heuristic), from hereon called the ‘valid heuristic condition’, one condition included both information on a valid and an invalid energy estimating heuristic (the time switched on heuristic), from hereon called the ‘joint-heuristic condition’ and the control condition did not provide participants with information on the heuristics. The original study design also included a fourth condition, which included information about the invalidity of the time switched on heuristic only, but as the recruitment of participants proved to be a challenge, this condition was subsequently omitted from the study. This condition was selected for omission specifically because it was expected that it would be unlikely that informing participants about the invalidity of a heuristic only would result in changes in energy estimations as it would not provide participants with information on which heuristic to instead. Measures of energy literacy and energy consumption were taken before and after the information provision to assess the impact of the information provision.

8.1.2 Aims and hypotheses

The present study aimed to explore the extent to which the use of energy judgement heuristics can be changed and whether this can in turn improve energy literacy and energy conservation. The information was expected to have an effect on device energy literacy, activity energy literacy and energy conservation. The following sections will discuss the hypotheses for each of these dependent variables.

8.1.2.1 Device energy literacy

First, it was expected that changes in device energy literacy after the intervention would differ across conditions. Specifically, participants in the joint-heuristic condition were expected to improve their device energy literacy scores the most —as they were able to replace the use of an incorrect heuristic with a valid heuristic. Participants in the valid heuristic condition were expected to still improve their device energy literacy — although less than the participants in the other experimental condition, because they only received information on the valid heuristic and therefore may be expected to use this heuristic in addition to the invalid heuristic. Participants in the control condition were not expected to improve their device energy literacy. This hypothesis would be confirmed if the difference in device energy literacy before and after the intervention differed across conditions (a significant interaction between ‘study phase’ and ‘condition’) and planned comparisons confirm that these differences were largest for the joint-heuristic condition, followed by the valid heuristic condition and this difference was not significant in the control condition (*hypothesis 1*).

Furthermore, if the intervention had an effect on device energy literacy this effect was expected to be mediated by the change in the use of heuristics (*hypothesis 2*). That is, participants in the joint-heuristic condition were predicted to have increased the use of the heat heuristic and decreased the use of the time switched on heuristic, which resulted in the improved levels of device energy literacy. Moreover, in the valid heuristic condition, participants were expected to have increased the use of the heat heuristic, which in turn resulted in improved device energy literacy. Any possible changes in energy literacy after the intervention in the control condition were not expected to be mediated by the use of heuristics. Furthermore, other heuristics were not expected to mediate any changes in energy literacy because these heuristics were not addressed in the intervention.

8.1.2.2 Activity energy literacy

The changes in activity energy literacy after the intervention were expected to differ across conditions in a similar way, as reflected in a significant interaction between study phase and condition. Again, planned comparisons were expected to show that these differences were largest for the joint-heuristic condition, followed by the valid heuristic condition and this difference was not expected to be significant in the control condition (*hypothesis 3*).

Again, if the intervention had an effect on activity energy literacy, this effect was expected to be mediated by the change in the use of the heuristics. The changes in activity energy literacy in the joint-heuristic condition was expected to both be mediated by the use of the heat heuristic as well as the use of the time switched on heuristic whereas the changes in activity energy literacy in the valid heuristic condition was expected to be mediated by the use of the heat heuristic only. No mediating effects were predicted for the control condition, nor was the use of any other heuristics expected to mediate the changes in activity energy literacy (*hypothesis 4*).

Any improvement in activity energy literacy was expected to induce energy saving behaviour (see next paragraphs) because participants were better able to select energy saving activities that have a large impact on energy savings. Therefore, it was predicted that participants who had improved their activity energy literacy, had improved the impact of their energy saving behaviour significantly more compared to participants who have not improved their activity energy literacy after the intervention (*hypothesis 5*).

8.1.2.3 Energy consumption

Third, a similar pattern to that expected in the energy literacy variables was expected for the energy consumption of the participants. That is, changes in energy consumption after the intervention were expected to depend on the condition that the participants were in. Again, the largest effect (i.e. the highest levels of energy conservation) was expected for the joint-heuristic condition, followed by the valid heuristic condition and no changes were predicted for the control group, as participants in this condition did not receive information on how to best evaluate the energy use in their household (*hypothesis 6*).

8.2 Method

This study was designed to assess whether energy literacy and energy saving behaviour can be improved by informing participants about the validity of heuristics used to estimate the energy use of a household device. Because the University of Bath monitors the energy consumption of the halls of residents in student accommodation, and because young people, right at the beginning of their time as independent energy consumers, are a topic of particular interest, the study took place in university accommodation on campus. Flats with participating residents were randomly assigned to one of three conditions: the valid heuristic condition, the joint heuristic condition or the control condition. Posters were designed and distributed across the flats to communicate the respective information. Participants filled in a survey before and after the information provision in which the two types of energy literacy were measured. Because the study included repeated measures as well as independent conditions, the study had a mixed between-within-subjects design (Tabachnick & Fidell, 2013). The advantage of this design was that changes over time could be detected, which would not have become apparent in a between subjects only design. Furthermore, the different conditions were necessary to be able to attribute any changes in energy literacy to the experimental manipulation rather than any external factors that may have changed energy literacy.

8.2.1 Ethical approval

Approval was granted by the University of Bath Department of Psychology ethics committee, reference number 14-229.

8.2.2 Participants

Participants were 108 (M_{age}=18.71, SD_{age}=.84, 52.8% male) first-year undergraduate students living in 26 different flats on campus of the University of Bath. The study was advertised as an energy saving challenge and participants were recruited through online and off-line advertising, as well as going door-to-door to recruit participants. Participants were incentivised to participate and to save energy during the study by awarding the participants of the flats that saved the most energy in their housing block with a £150 prize. Because energy consumption was included in residents' rent, this prize was introduced to simulate the financial incentive that is generally associated with energy conservation.

8.2.3 Materials

Two posters were designed by a graphical designer to convey the information on the heuristics. One poster addressed the heat heuristic only, describing the relationship between the heat that a device produces and the energy it uses and emphasised that this heuristic can be helpful when estimating energy use of household appliances using an example ("*A tumble dryer produces about 3 times more heat than a hairdryer and also consumes about 3 times more energy per* *minute than a hairdryer*") and graphical images were included to ease the understanding (see Figure 19). The other poster informed residents about the validity of both heuristics by presenting the time switched on heuristic as a 'bad' heuristic and the heat heuristic as a 'good' heuristic, again with the corresponding examples (the previous example and "*Although a fridge-freezer is usually left on longer than a laptop, it consumes 10 times more energy per minute!*") and the corresponding graphical images (see Figure 18). The two posters were designed to match in design and the only difference between them was the addition of the information on the time switched on heuristic.

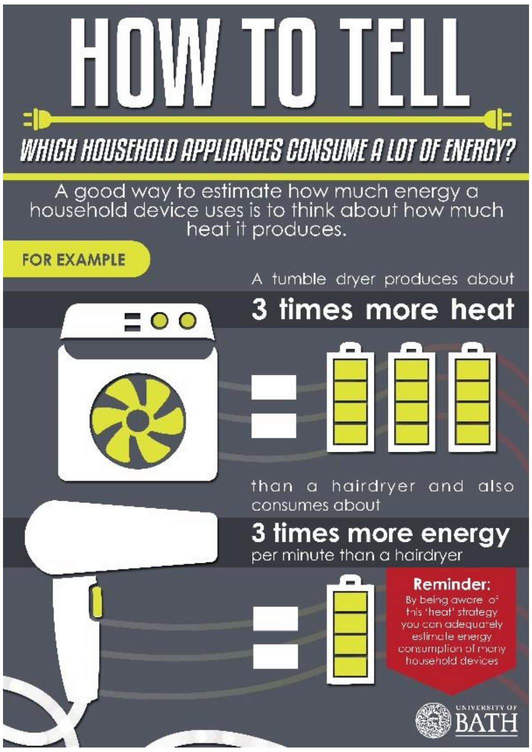

Figure 19: Poster for the valid heuristic condition

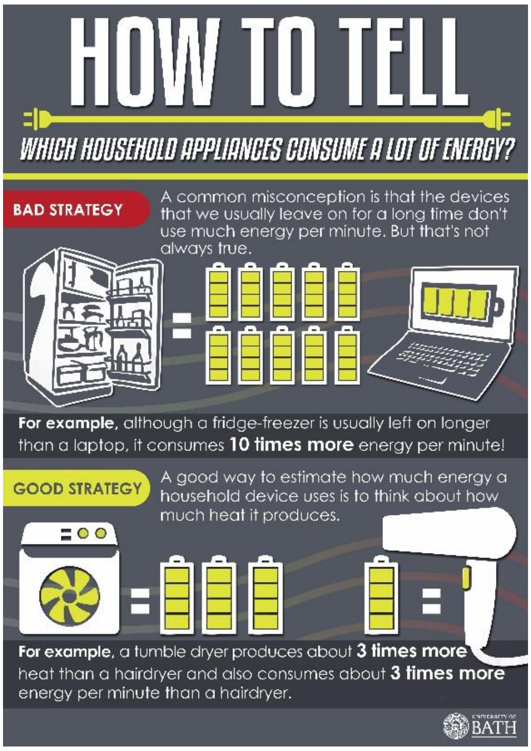

Figure 18: Poster for the joint heuristic condition

Participants completed one online questionnaire before the posters were distributed, and one afterwards. The first questionnaire included items on demographics and two tasks to assess energy literacy. Similar to the method in the study reported in Chapter 6, participants completed a rank-order task in which they ordered 10 household appliances (the same as in Chapter 7), from most energy consuming to least energy consuming similar to the task used by Baird and Brier (1981), but considering their energy use for one minute of use instead of one hour. This task was chosen to assess device energy literacy because it was found to be superior over alternative energy judgement tasks as discussed in Chapter 5 and 6.

Next, participants were asked to what extent (from 1: *Did not consider this at all* to 5: *Strongly considered this*) they had used the heuristics that participants had most frequently reported to have used in the study reported in Chapter 7 (the heat-, size-, time switched on-, speed-, activity[1], and intensity- heuristic). The five heuristics that were not addressed in the intervention were included to check that participants only changed the use of heuristics that were addressed in the intervention. For the second energy literacy task, participants rated eight energy saving activities by how often they engaged in the activities (on a Likert scale from 1: *never*, to 5: *every/all the time*) and the financial savings thought to result from each activity on a scale from 1 (*less than £10 per year*), 2 *(£10 or more per year*) to 7 (*£60 or more per year*), with intermediate responses increasing in £10 intervals. Five of these activities concerned reducing the use of specific devices (e.g. "*Setting your washing machine to 30 degrees*", "*Only boiling the water you need*") whereas others did not relate to a specific appliance (e.g. "*Turning down the thermostat by 1 degree Celsius*"), and included both curtailment behaviours as well as energy efficiency behaviours.

The second survey included similar demographic items to match participants across the two surveys. Furthermore, the same appliance rank-order task with the rating of the use of the energy judgement heuristics was included, as well as the items on energy saving activities and the associated monetary savings. Furthermore, the last part of the survey included two questions to check if the participants had noticed the poster in their kitchens and could validly recall the message of the poster ("*If you have noticed a new poster about energy consumption in your kitchen, can you describe the main message of the poster?*").

This study was originally also designed to investigate if individual differences in environmental values could predict levels of energy literacy. Therefore, measures of biospheric values, personal norms and environmental identity were included in the survey. However, as discussed above, recruitment turned out to be more challenging than expected. To make it more appealing to participate, participants were permitted to skip the last part of the survey which consisted of these individual difference items. This ensured that sufficient participants took part in the study, but unfortunately, this meant that 18.5% of the final sample (those who completed both surveys) did not respond to the individual difference items. This is a very high percentage of missing data, especially for a relatively small sample as was the case in this study. Furthermore, it could not be safely assumed that participants who skipped these items would not have scored differently on these items. Therefore, responses to these items were likely to be biased, and were excluded from further analysis, meaning that the relation between the individual differences and energy literacy was not tested in this study.

[1] The activity heuristic was not among the most frequently reported heuristics in Chapter 7 but was accidently included instead of the task size heuristic in this study.

8.2.4 Procedure

After signing up for the study, participants received an email with the link to the first survey. Participants were given two weeks to fill in the online-survey but as response rates were low (34.72% of residents that had signed up for the study), the remainder of the responses were obtained by going door-to-door with paper surveys. After sufficient responses were collected for the first survey (*N*=168), the flats were randomly assigned to conditions using an online random number generator and the respective posters were distributed across the flats, one on each communal kitchen's noticeboard (see the flowchart of the process of data-collection and poster distribution in Figure 20). After four weeks, the flats were checked to see if the posters were still in place and 19 posters were replaced because the previous ones were removed by residents and posters were moved to ensure visibility where necessary. The responses to the questions that were included in the survey to check if the participants had noticed the posters will be addressed in section 8.2.6 to assess if sufficient exposure to the posters could be assumed despite the removal of these posters.

Five weeks after the posters were first distributed across the flats, an email with the second survey was sent to the participants. Again response rates were low (49.40% of the participants who had filled in the first survey) and the remainder of the responses were collected by going door-to-door using paper surveys. Participants' responses were matched across surveys using the address that was reported in both surveys. The number of participants that completed both surveys after this follow-up data collection was 108, meaning that the drop-out rate between the two surveys was 35.71%.

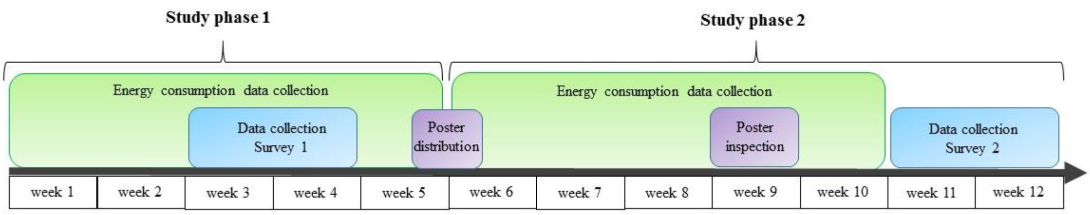

Figure 20: Flow chart of the procedure of data collection and poster distribution

8.2.5 Measuring the effect of the intervention

The effect of the intervention on device literacy, energy saving activity literacy and energy consumption was measured to assess the impact of the intervention.

To infer participants' device energy literacy, their performance on the device rank-order task was evaluated. A list of the 'correct' order of the appliances was created by taking the mean Wattage reported for each device on various websites (Draft Logic, 2008; FrequencyCast, 2012; Michael Bluejay Inc., 2012; U.S. Department of Energy, 2012), similar to the method in the study reported in Chapter 3. To reflect the agreement between the participants' rank-order and the 'correct' order, a correlation between the two was computed using a Spearman correlation as this method is appropriate for ranked data. This was done for both the before and after intervention ranks-orders, meaning that each participant had two correlational scores reflecting their skill on this task before and after the intervention. Because the scores were not normally distributed, as is to be expected of correlational data, a Fisher's *r*-to-*Z* transformation was performed on these variables. After these transformations, the data from both time points were normally distributed as indicated by Q-Q plots.

The second type of energy literacy was measured by asking participants how much money they thought they could save with particular energy saving activities before and after the intervention. Similar to the previous variable, a list of 'correct' values for each activity was created by taking the mean annual savings reported in various online sources (Energy Saving Trust, 2015; Energy UK, 2015; This is Money, 2014). Again, a Spearman correlation between the rating of the participant and the correct values was computed for both the before and after intervention ratings. Scores were transformed using Fisher's transformation to obtain normal distributions for these scores, which was confirmed by Q-Q plots.

Furthermore, variables were created to reflect the extent to which participants engaged in impactful energy saving behaviour before and after the intervention, to test hypothesis five. Participants' ratings of the extent to which they engaged in energy saving behaviour was multiplied with the annual monetary saving associated with each activity (calculated by the researcher) to obtain a score that reflected the impact of their energy saving behaviour.

The total energy use in the participating flats was measured in kWh for 5 weeks before and 5 weeks straight after the posters were distributed across the flats. Because participants shared their facilities with other flatmates, no individual energy consumption could be measured and energy consumption was therefore measured per flat. Furthermore, not all residents in each flat participated in the study, which meant that the energy consumption data also included energy use of non-participants. As not enough data was available on gas use for the participating flats, only electricity consumption was measured, which means that this measure did not capture changes in hot water use and the heating of the flats. Several flats had two meters (for west and east sides of the flat or for lights and other electricity consumption), and the mean of both meters were computed for these flats.

Initially, 54 flats had signed up for the energy saving challenge, but participants of 21 flats did not fill in the second survey and therefore no energy data was collected from these flats. Data from one flat could not be obtained after the intervention because the meter malfunctioned. Data from seven further flats could not be obtained as these did not have their own meters. Therefore, energy data was only obtained for 26 flats. Flats consumed a total average of 1115.15 kWh (*SD*=575.61) over the 5 weeks before the intervention and a total average of 1123.27 kWh (*SD*=567.13) over the 5 weeks after the intervention.

8.2.6 Manipulation check

At the end of the second survey, participants were asked if they had noticed a new poster about energy consumption in their kitchen in the last few weeks to check their awareness of the poster. The responses showed that the majority of participants in the experimental conditions (the only participants that had this poster in their kitchen) noticed the poster (62.5%), whereas some were not sure (19.4%) and few reported not to have noticed the poster (18%). Although these figures suggest that not all participants remembered seeing the poster, it does show that the poster had drawn sufficient attention for most participants to be able to recall seeing it. It is likely that the participants who did not report to have seen the poster or were unsure may still have noticed and read the poster, but did not recall the poster at the time of the second survey. That is, the information of the poster may have been processed by the participants, perhaps without conscious awareness, and these participants may therefore still have received the information on the heuristics.

A minority of the descriptions of the poster indicated some misinterpretations of the poster (e.g. "*It was saying that bigger appliances would use more energy than smaller ones, even if they are on for less time as they consume more power*.") or a disinterest (e.g. "*No, we took it down as fast as possible because it was boring and no one wanted to look at it.*"). However, most of the participants had grasped the main message of the posters (e.g. "*Hot appliances use more energy*" or "*It told us about what uses a lot of energy and how devices that have to affect temperature like fridges use a lot more energy than devices like laptops. Devices which are on for prolonged periods of time are not necessarily using less energy per unit time*"). This further underlines that exposure to the information on the heuristics can be assumed in the experimental conditions. For this reason, and because the sample in the current study did not leave much leeway for the exclusion of participants, no participants were excluded from the analysis.

Most participants in the control condition validly reported not to have seen a poster (64.70%), few were unsure (11.76%) whereas almost a quarter (23.5%) of participants incorrectly reported to have seen the new poster on energy consumption. This could suggest the presence of other posters about energy consumption in the kitchens, but this is unlikely as these were not apparent when the flats were visited during the second round of data collection. Alternatively – and more critically – this could suggest that participants had noticed the experimental posters when visiting other flats, and cross-contamination may have occurred. If this was the case, then this will become apparent in the analyses, as the effect of the intervention will be similar across conditions.

8.2.7 Analyses

Three groups of analyses were performed to test the hypotheses for each dependent variable, stated in 8.1.2.

To test the first hypothesis, a split-plot ANOVA was performed on the device energy literacy variable to test the effect of the intervention by assessing the interaction between condition and study phase. This type of analysis (also called mixed designs ANOVA or mixed between-within subjects ANOVA) is appropriate for repeated measures study designs that also includes (at least two) groups (conditions) and where the dependent variable is continuous (Dancey & Reidy, 2011; Tabachnick & Fidell, 2013), which is the case in this analysis.

The results of this analysis suggested no effect of conditions on device energy literacy and possible cross-contamination across conditions because device energy literacy was improved across all conditions (see section 8.3.1). Therefore, the follow-up analyses which tested the mediating effects (*hypothesis 2*) was performed on device energy literacy collapsing across conditions. A mediation analysis for each heuristic explored whether their use could account for the changes in device energy literacy after the intervention. It was expected that only the use of the heat heuristic and the time switched on heuristic would significantly mediate the change in device energy literacy as these were the only heuristics that had been addressed in the intervention.

Mediation analysis quantifies and tests the indirect effect of the mediator (*M*) in the X-Y predictive relationship (Preacher & Hayes, 2008). The indirect effect of independent variable *X* on dependent variable *Y* through *M* is measured with *ab*, the product of *a* (the coefficient of the effect of *X* on the mediator *M*) and *b* (the coefficient of the effect of the mediator *M* on *Y*, partialling out the effect of X on Y) (see Figure 21; Preacher & Hayes, 2008). The total effect of X on Y is the sum of the direct and indirect effects: $c = c' + ab$, therefore c' is the direct effect of X on Y controlling for the indirect effect of *ab*. If c' is smaller than *c* but significantly different to 0, the mediation is said to be partial (Tabachnick & Fidell, 2013).

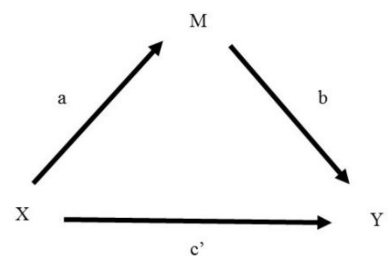

Figure 21: Illustration of a mediation design, adapted from Preacher & Hayes, 2008

Because of the repeated measures design of this study, a conventional mediation analysis, which assumes completely independent measures, could not be applied to this data. The mediation effect was therefore tested using linear mixed models, as this method is appropriate for repeated measures data that includes continuous predictors (West, Welch, & Galecki, 2014). To estimate the significance of indirect effect *ab*, 1000 bootstraps with replacement were performed to obtain a confidence interval around the regression coefficient of this path (Preacher & Hayes, 2008). This method has been found to result in more valid confidence limits compared to a traditional approach that involves computing Z-statistics from the estimate and comparing this to a critical value (MacKinnon, Lockwood, & Williams, 2004). That is, the bootstrapping approach produces nonparametric approximations of the sampling distributions of the indirect effects and thereby does not require the data to be normally distributed (MacKinnon, Lockwood, & Williams, 2004). However, linear mixed models do require homoscedasticity and an absence of outliers (Winter, 2013), which were checked for each analysis.

The second group of analyses consisted of a similar split-plot ANOVA on activity device energy literacy including an interaction between study phase and condition to test the third hypothesis. A mediation analysis was planned if the intervention was found to have an effect on this energy literacy. However, the results showed that the intervention had no effect on activity energy literacy, not even when collapsing across conditions (see section 8.3.2). Therefore, the mediation analysis on activity energy literacy is not included in the following result section but is included in Appendix .

However, the fifth hypothesis, which predicted that participants who did improve their activity energy literacy would improve the impact of their energy saving behaviour, was still tested. That is, it was possible that the participants who improved their activity energy literacy as a result of the intervention did engage in more effective energy saving behaviour. A split-plot ANOVA on the impact of the energy saving variables (before and after the intervention) was performed to see if participants with improved activity energy literacy engaged in more efficient energy saving behaviour after the intervention. Because the intervention was not found to have a different effect across the conditions, this analysis was also performed by collapsing across conditions.

Finally, to assess the impact of the intervention on actual energy savings, a split-plot ANOVA was performed on energy consumption including an interaction between condition and study phase.

8.3 Results

8.3.1 Effect of intervention on device energy literacy

As discussed above, to assess the effect of the intervention on the two types of energy literacy a split plot ANOVA was performed. The general assumptions that apply to ANOVAs also apply to this analysis, including approximate normal distribution of the dependent variable for each cell, no significant outliers and homogeneity of variances across the cells (Dancey & Reidy, 2011; Tabachnick & Fidell, 2013). Sphericity assumptions only need to be met when the study design includes more than two within-subjects levels (Dancey & Reidy, 2011), which is not the case for the current study. Additionally, split plot ANOVA also assumes homogeneity of intercorrelations, which means that for each condition, the pattern of intercorrelations between the repeated measures should be the same (Pallant, 2010). This assumptions can be tested with Box's *M* statistic, for which it has been recommended to use an alpha level of .001 as it is highly sensitive (Pallant, 2010).

A split plot ANOVA was performed on the device energy literacy variables, including condition and study phase as independent variables and their interaction. The distributions across cells were checked with Q-Q plots of the residuals, and the assumption of normality seemed to hold. A conservative approach in regards to outliers was taken to ensure that no meaningful data was omitted. Following Tabachnick and Fidell's recommendations for univariate outliers (2013), values that had a *z*-score above 3.29 were classified as outliers. For this dependent variable, no *z*-scores were found to exceed this value, and therefore no data was removed. Furthermore, the assumption of homogeneity of intercorrelations was not found to be violated ($M(6,132864.90)=18.65$, $p=.006$). Homogeneity of variances were tested using Levene's test and seemed to hold for the device energy literacy variable after the intervention ($F(2,105)=.44$, $p=.65$). However, the assumption was violated for the device energy literacy variable before the intervention, although the *p*-value was just significant ($F(2,105)=3.11$, $p=.048$) and tests for homogeneity have been criticized for being too sensitive (van Belle, Fisher, Heagerty, & Lumley, 2004). Moreover, F-tests have been demonstrated to be robust against heteroscedasticity as long as group sizes are not negatively correlated with variances (Box, 1953). The lowest variances were found in the joint heuristic condition which included the smallest number of participants, suggesting a positive correlation between group size and variances, and the robustness of F-tests against the heteroscedasticity can therefore be assumed (Box, 1953). Furthermore, because no non-parametric equivalent of the split plot ANOVA exists (Pallant, 2010), the analysis was carried out as planned but findings were interpreted cautiously.

Results showed no significant interaction between study phase and condition, as such there were no differences in the change in energy literacy across the conditions

($F(2,105)=1.27$, p =.29), contradicting the first hypothesis. However, the results did show a significant main-effect of study phase, meaning that after the intervention participants in all conditions showed enhanced performances on the rank-order task ($F(1, 105) = 17.91$, p <.001) (see Figure 22).

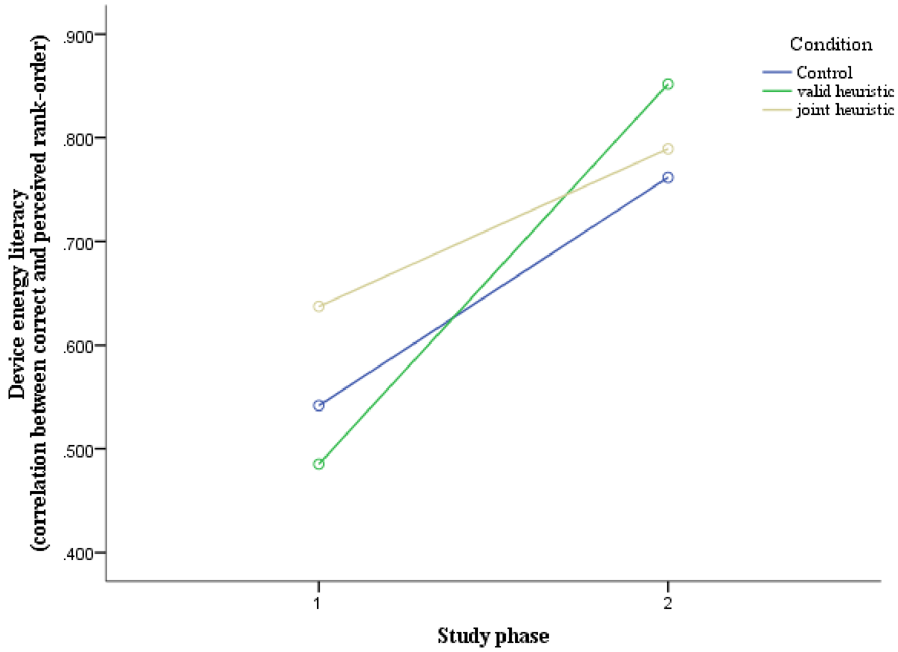

Figure 22: Effect of study phase on device energy literacy per condition. Graphs illustrates the results of the split plot ANOVA showing a significant main-effect of study phase on device energy literacy
Note: study phase 1 indicates measures before the intervention and study phase 2 indicates measures after the intervention

Because these results showed that participants improved their device energy literacy, but this change was not found to differ across conditions, this might indicate cross-contamination across conditions — which is in line with the results of the manipulation check reported in section 8.2.6. Therefore, the mediation analyses was performed by collapsing the data across conditions.

An initial analysis showed a significant total effect of study phase on device energy literacy (c =.263, $\chi^2(1)=19.50$, p<.001), indicating that device energy literacy was significantly higher after the intervention (consistent with the results of the split plot ANOVA). The mediation analyses reported in the following sections explored if this change in energy literacy could be explained by the changes in the use of the heuristics as a result of the intervention, as predicted by the second hypothesis. As stated in section 8.1.2, only the heat and time switched on heuristics were expected to mediate the change in device energy literacy. However, a mediation analysis for each heuristic was performed to confirm that only the use of these two heuristics mediated the improved device energy literacy and thereby served as a test that any changes might reasonably be attributed to the information provision in this study.

8.3.1.1 Mediation model for the size heuristic

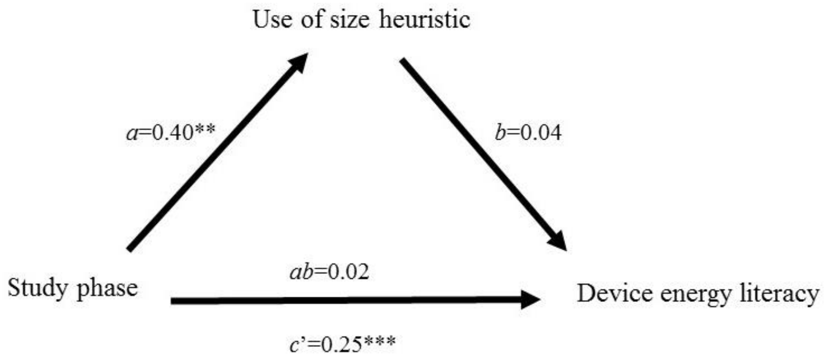

Figure 23: Diagram of the mediating effect of the size heuristic. The diagram displays regression coefficients of the direct effect of study phase on device energy literacy and the indirect effects through the use of the size heuristic
*Note: **<.01, ***<.001*

The residual plot confirmed the assumption of homoscedasticity and that no outliers were present for this mediation analysis. The results of the mediation analysis for the size heuristic showed a non-significant mediation effect (ab=0.02, 95%CI [-0.01, 0.05]), in line with the third hypothesis. That is, the change in the use of the size heuristic did not account for a significant amount of variance in the relation between study phase and device energy literacy (see Figure 23). The direct effect of study phase on device energy literacy was still significant as would be expected with a non-significant indirect effect (c'=0.25, 95% CI [0.12, 0.37]). Although the results did indicate that participants reported using the size heuristic more often after the intervention (a=0.40, $\chi^2(1)=8.48$, p<.01), the use of this heuristic did not impact the validity of the rank-order task (b=0.04, $\chi^2(1)=2.18$, p=.14).

8.3.1.2 Mediation model for the intensity heuristic

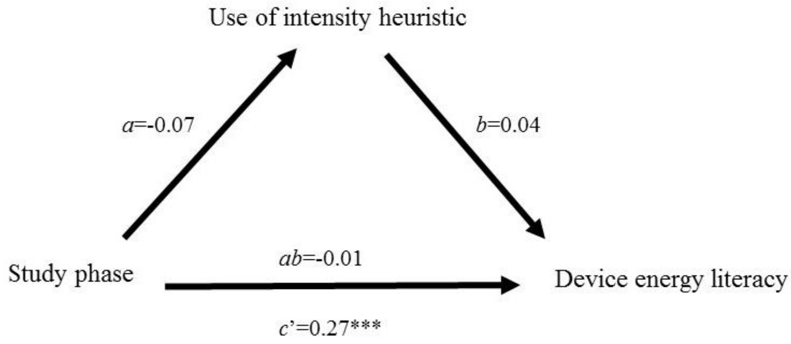

Figure 24: Diagram of the mediating effect of the intensity heuristic. The diagram displays regression coefficients of the direct effect of study phase on device energy literacy and the indirect effects through the use of the intensity heuristic
*Note: ***<.001*

Homoscedasticity assumptions were shown to hold on the residual plot and no outliers were present for this mediation analysis. As hypothesised, no significant mediation effect was found for the intensity heuristic (*ab*=-0.01 95% CI [-0.02, 0.01]), meaning the use of the intensity heuristic could not account for the positive effect of study phase on device energy literacy (see Figure 24). Again, the direct effect of study phase on device energy literacy was still found to be significant in the mediation model (*c*'=0.27, 95% CI [0.16, 0.39]). Furthermore, the use of this heuristic was not found to change across study phases (*a*=-0.07, $\chi^2(1)=0.62$, *p*=.43) nor did the use of this heuristic have an effect on how well participants could estimate the energy use of the appliances (*b*=0.04, $\chi^2(1)=1.32$, *p*=.25).

8.3.1.3 Mediation model for the activity heuristic

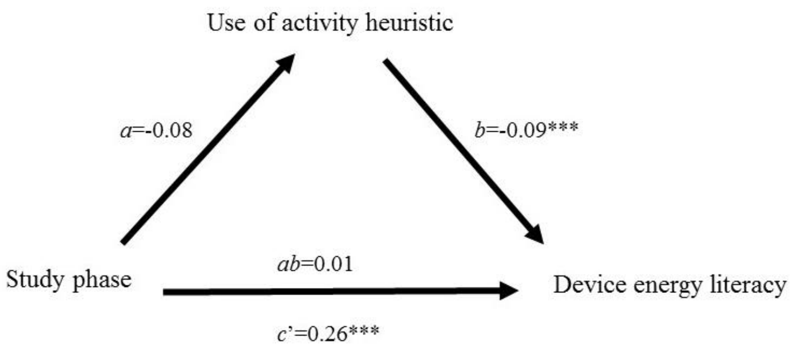

Figure 25: Diagram of the mediating effect of the activity heuristic. The diagram displays regression coefficients of the direct effect of study phase on device energy literacy and the indirect effects through the use of the activity heuristic
*Note: ***<.001*

The residual plot demonstrated acceptable levels of homoscedasticity and no outliers for this mediation analysis. The use of the activity heuristic was not found to significantly mediate the effect of study phase on device energy literacy (*ab*=0.01, 95% CI [-0.02, 0.04], see Figure 25), congruent with the second hypothesis. The direct effect of study phase on device energy literacy was still significant as would be expected with an insignificant indirect effect (*c*'=0.26, 95% CI [0.14, 0.38]). Furthermore, the use of this heuristic was unchanged across study phases (*a*=-0.08, $\chi^2(1)=0.52$, *p*=.47). However, the more participants reported to use this heuristic, the lower their device energy literacy scores were (*b*= -0.09, $\chi^2(1)=11.43$, *p*<.001), suggesting that the use of this heuristic negatively impacted the validity of the rank-order of the appliances.

8.3.1.4 Mediation model for the heat heuristic

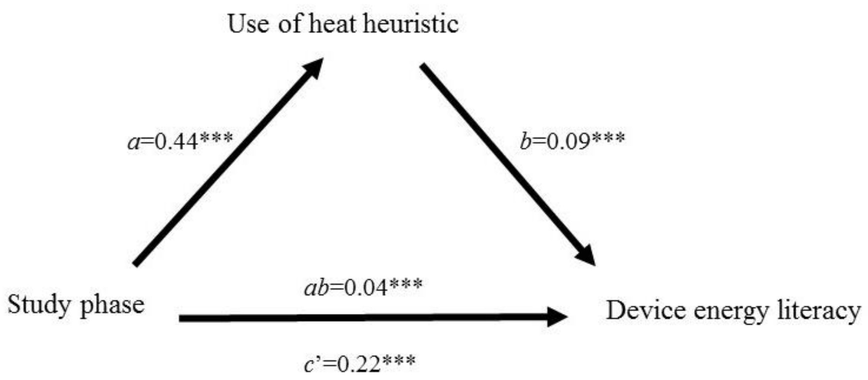

Figure 26: Diagram of the mediating effect of the heat heuristic. The diagram displays regression coefficients of the direct effect of study phase on device energy literacy and the indirect effects through the use of the heat heuristic
*Note: ***<.001*

Again, homoscedasticity was confirmed and no outliers were present for this mediation analysis. In line with the expectations stated above, a significant mediation effect was found for the heat-heuristic (see Figure 26). That is, the effect of study phase on device energy literacy was significantly mediated by the use of the heat heuristic (*ab*=0.04, 95% CI [0.02, 0.08]), confirming the second hypothesis. However, the direct effect of study phase on device energy literacy was still significant in this mediation model (*c*'=0.22, 95% CI [0.10, 0.34]), meaning that a partial mediation effect was found. Computing the ratio of the indirect effect over the total effect (*ab*/*c*=0.18) shows that 18% of the total effect was mediated by the use of the heat heuristic (Preacher & Kelley, 2011). Inspecting the individual coefficients in the model, it is evident that study phase had a positive relationship with how much participants used the heat heuristic, meaning that participants used this heuristic more after the intervention (*a*=0.44, $\chi^2(1)= 8.14$, *p*<.001). Furthermore, the more participants indicated using this heuristic, the better they were at estimating the relative energy use of the household appliances (*b*=0.09, $\chi^2(1)$=13.82, *p*<.001), confirming the validity of this heuristics.

8.3.1.5 Mediation model for the speed heuristic

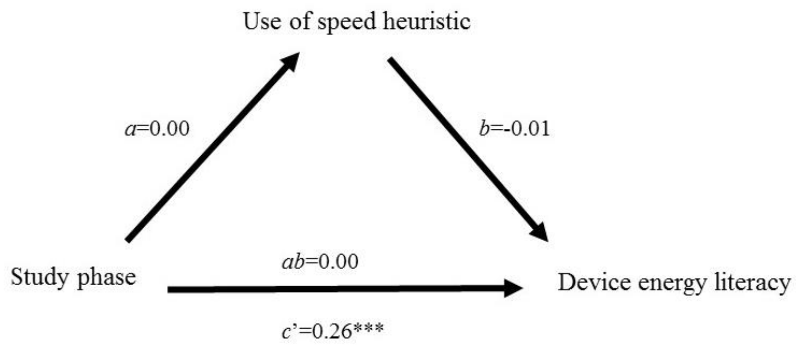

Figure 27: Diagram of the mediating effect of the speed heuristic. The diagram displays regression coefficients of the direct effect of study phase on device energy literacy and the indirect effects through the use of the speed heuristic
*Note: ***<.001*

The residual plot confirmed homoscedasticity for this mediation analysis, and no outliers were present. As expected, no mediation effect was found for the speed heuristic (*ab*=0.00 95% CI [-0.01, 0.01], see Figure 27). Because the mediation effect was practically 0, *c'* equalled *c* which was a significant direct effect of study phase on device energy literacy (*c*'=0.26, 95% CI [0.15, 0.39]). Furthermore, the frequency of the use of this heuristic remained the same after the intervention (*a*=0.00, $\chi^2(1)$= 0.00, *p*=.99) and the use of the speed heuristic was not found to affect the performance on the rank-order task (*b*= -0.01, $\chi^2(1)$=0.24, *p*=.62).

8.3.1.6 Mediation model for the time switched on heuristic

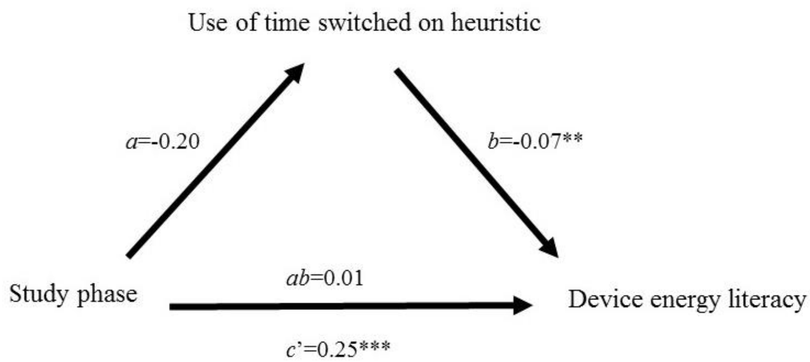

Figure 28: Diagram of the mediating effect of the time switched on heuristic. The diagram displays regression coefficients of the direct effect of study phase on device energy literacy and the indirect effects through the use of the time switched on heuristic
*Note: **<.01 ***<.001*

The residual plot showed homoscedasticity and no outliers for this mediation analysis. Contrary to the hypothesis, the use of the time switched on heuristic did not mediate the relation between study phase and device energy literacy (*ab*=0.01, 95% CI [-0.01, 0.04]. The direct effect of study phase on the performance on the ranking task was found to be significant (*c*'=0.25, 95% CI [0.13, 0.37]). After the intervention, this heuristic was not significantly used less in the rank-order task, although the coefficient does suggest a declining tendency of the use of this heuristic (a= -0.20, $\chi^2(1)$= 1.97, p=.16). Furthermore, the negative impact of the use of this heuristic on the validity of the energy estimations was confirmed (b= -0.07, $\chi^2(1)$=8.96, p<.01).

8.3.2 Effect of intervention on activity energy literacy

Another split plot ANOVA was performed on the activity energy literacy variables, including condition and study phase as independent variables and the interaction between these variables was also included. Normal Q-Q plots of the residuals of the model confirmed approximate normal distributions across cells. One observation had a *z*-score larger than the advised cut-off point of 3.29 (3.87) and was therefore removed from the data (Tabachnick & Fidell, 2013). The assumption of homogeneity of intercorrelations was found to hold ($M(6,140182.10)$=10.75, p=.11). Homogeneity of variances were tested using Levene's test and, similar to the analysis on the rank-order task, homoscedasticity seemed to hold for device energy literacy after the intervention ($F(2,103)$=1.89, p=.16), but the assumption was violated for activity energy literacy before the intervention ($F(2,103)$=3.55, p=.032). Because the p-value was again not very small, and for aforementioned reasons (section 8.3.1), the analysis was still performed but results were interpreted cautiously.

Results showed no significant interaction between study phase and condition ($F(2, 103) = .09$, $p = .91$), suggesting that there were no differences across conditions in the change of the accuracy of the perceived impact of energy saving activities (see Figure 29). Furthermore, no main-effect of study phase was found, meaning that activity energy literacy was not significantly different before and after the intervention when collapsing across conditions ($F(2, 103) = 1.24$, p =.27).

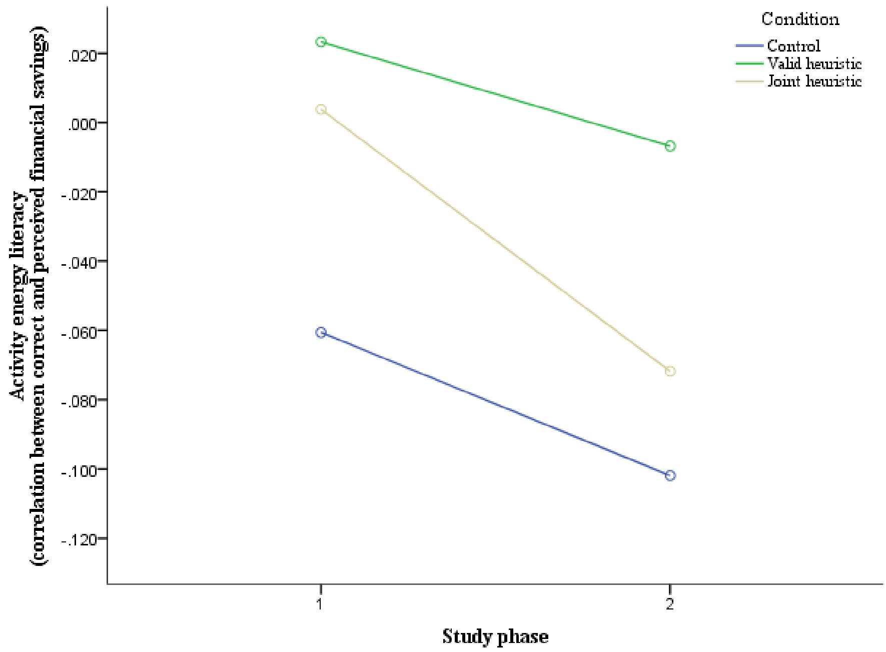

Figure 29: Effect of study phase on activity energy literacy per condition. Graphs illustrates the results of the split plot ANOVA showing no significant interaction between condition and study phase nor a significant main-effect of study phase on activity energy literacy
Note: study phase 1 indicates measures before the intervention and study phase 2 indicates measures after the intervention

Because activity energy literacy was not found to have changed as a result of the intervention, the mediation analyses for activity energy literacy are not reported here, but instead are included in Appendix GI. These analyses showed that any changes in activity energy literacy across study phases (which were not found to be significant) were not mediated by the use of any of the energy judgement heuristics.

The fifth hypothesis predicted that participants who had improved their activity energy literacy, had improved the impact of their energy saving behaviour significantly more compared to participants who had not improved their activity energy literacy after the intervention. Even though the activity energy literacy was not found to have improved significantly, this hypothesis could still be tested, as it is possible that the participants who did improve their activity energy literacy would engage in more efficient energy saving behaviour as a result of this improvement. Participants were grouped into either an ‘improved’ -group if they had higher activity energy literacy scores after the intervention (N=51), or an ‘unimproved’-group if their scores remained the same or decreased after the intervention (N=54). A split plot ANOVA was performed on the impact of the energy saving behaviour variable, including the grouping variable and the study phase variable as independent variables as well as their interaction to assess hypothesis five.

Normal Q-Q plots of the residuals of the model confirmed approximate normal distributions for the impact of the energy saving variables before and after the intervention. No energy use scores had a higher *z*-value than 3.29 and therefore no outliers were detected (Tabachnick & Fidell, 2013). The assumption of homogeneity of intercorrelations was found to hold (M (3,1932453.34)=1.34, p=.73). Homogeneity of variances were tested using Levene's test and the assumption seemed to hold for the variable measuring energy use before (F(1,103)=1.44, p=.23) and after the intervention (F(1,103)=0.31, p=.58).

The interaction between study phase and groups was not found to be significant (F(1, 103) = .00, p = .99) meaning that there were no differences between the two groups in the impact of their energy saving behaviour across study phases, disconfirming hypothesis five. However, a main-effect of study phase was found which revealed that both groups engaged in more efficient energy saving behaviour after the intervention (F(1, 103) = 6.82, p <.01).

8.3.3 Effect of intervention on energy consumption

Finally, a split plot ANOVA was run to assess the effect of the intervention on energy consumption, again including condition and study phase as independent variables as well as the interaction between these two. Normal Q-Q plots of the residuals of the model confirmed approximate normal distributions across cells. No energy use scores had a higher *z*-value than the recommended cut-off value of 3.29 and therefore no outliers were detected (Tabachnick & Fidell, 2013). The assumption of homogeneity of intercorrelations was found to hold (M(6,11908.97)=2.61, p=.89). Homogeneity of variances were tested using Levene's test and the assumption seemed to hold for the variable measuring energy use before (F(2,23)=0.78, p=.47) and after the intervention (F(2,23)=1.15, p=.34).

The results of the ANOVA revealed no significant interaction between study phase and condition (F(2, 23) = 0.24, p = .79), meaning that there were no differences across conditions in the change in energy consumption after the intervention, and thus no support for the sixth hypothesis was found, see Figure 30. Furthermore, no significant effect of study phase was found which shows that there was no change in energy use across the two study phases (F(2, 23) = 0.48, p = .50).

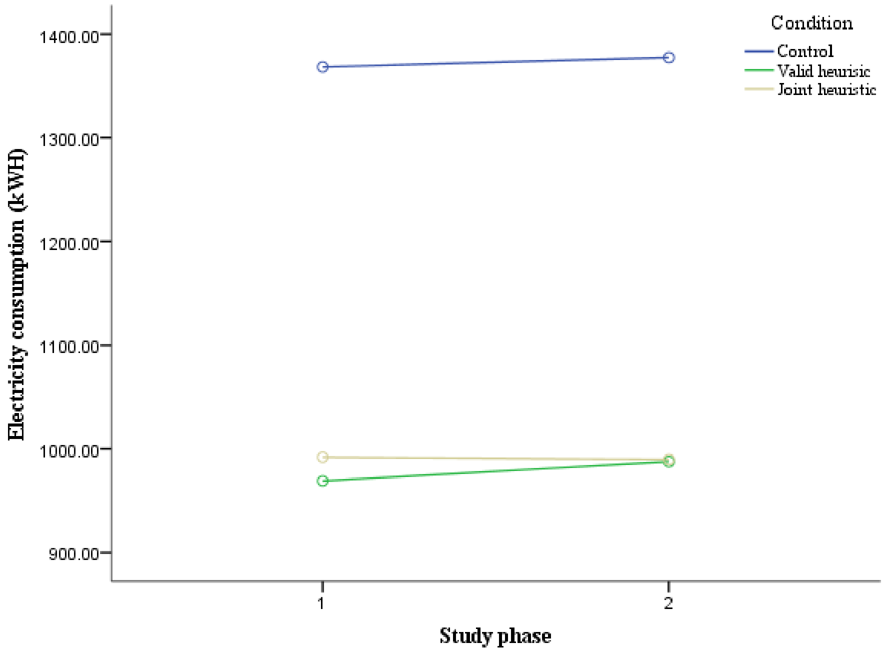

Figure 30: Effect of study phase on electricity consumption per condition. Graphs illustrates the results of the split plot ANOVA showing no significant interaction between condition and study phase nor a significant main-effect of study phase on energy use
Note: study phase 1 indicates measures before the intervention and study phase 2 indicates measures after the intervention

8.4 Discussion

8.4.1 Findings of the current study and methodological evaluations

The results showed that, there were no differences across conditions in terms of changes in device energy literacy, activity energy literacy or energy consumption. However, the performance on the rank-order task increased among participants across the conditions, suggesting that a cross-contamination may have occurred between conditions. That is, because the residents might be expected to visit each other's flats across campus, participants in the control condition may have observed the posters in the flats that were assigned to the experimental conditions. The results of the manipulation check suggested that participants in the control condition were generally aware of the posters that conveyed the information on the validity of the heuristics, which supports this interpretation. However, this finding could also be due to the creation of false memory, a phenomenon in which a person recalls an event that did not occur (Payne, Eie, Blackwell, & Neuschatz, 1996), which may have been prompted by the question about the poster in the survey. However, the changes in the use of the heuristics that were addressed on the posters (see next paragraphs) strongly suggests that most participants had learned the information on the heuristics through the posters. Although the accidental exposure to the posters may have been prevented by separating the conditions geographically (i.e. assign conditions to separate parts of the campus), flats were randomly assigned to conditions to exclude confounding effects such as income, background or motivations (as the rent prices of the accommodation differed across blocks). Therefore, having a control condition that would have been geographically isolated from the flats in the experimental conditions would not have benefited the design of the study as this could have introduced systematic biases.

Alternatively, participants may have been exposed to information on the energy consumption of household appliances coming from external information sources (e.g., informational campaigns, news, etc.), which may also explain the blanket improvement in device energy literacy. Participants may have been more sensitive to this information after signing up for the study, or may have even sought out the information on their own initiative after completing the first survey. Indeed, in the study reported in Chapter 6, participants that rank-ordered the appliances were very keen to learn the correct order, suggesting that it is plausible that participants in this study may similarly have been motivated to look up information about the energy consumption. Moreover, one could argue that the enhanced performance on the ranking task was due to a mere practice effect. However, no feedback was given after the first rank-order task, meaning practice alone cannot explain the participants performing better in the second study phase. Furthermore, if practice improved the performance on the ranking task, one would similarly expect an improvement on the other energy literacy task which was not found, further discrediting the practice effect as an explanation for the improvements in device energy literacy.

The significant improvement of device energy literacy after the intervention was mediated by the use of the heat heuristic, meaning that participants used this heuristic more after the intervention to complete the rank-order task and the more this heuristic was reported to be used the better participants' rank-order matched the 'true' rank-order. Because this heuristic was advertised as a good strategy for judging energy use on the posters, this further suggests that the improved device energy literacy was a result of the intervention. Moreover, this not only supports the validity of the heat heuristic, but therefore also suggests that information provision on the validity of this heuristic can change the use of this heuristic and thereby people's energy literacy. Furthermore, as expected, an opposite pattern was found for the time switched on heuristic, where participants tended to use this heuristic less after the intervention and its use had a negative impact on the energy literacy scores, although this mediation effect was not statistically significant. However, the negative impact of the use of this heuristic on device energy literacy *was* statistically significant, confirming that the more people used the heuristic in the rank-order task, the worse their device energy literacy scores were. It is likely that a stronger mediation effect of the heat heuristic compared to the time switched on heuristic can be attributed to the additional exposure as both posters addressed the heat heuristic whereas only one of the posters addressed the time switched on heuristic. Alternatively, it is possible that the heat heuristic was easier for participants to grasp, or that it was easier to increase the use of a heuristic that is valid rather than reducing the use of a heuristic that is invalid.

As expected, the extent to which people used the other heuristics could not explain any changes in device energy literacy after the intervention. However, participants were found to increase the use of the size heuristic in the second survey compared to the first, which may be due to a misinterpretation that was observed in the manipulation check data. That is, some of the qualitative survey descriptions of the posters suggested that a few participants may have misinterpreted the information on the poster for the advertisement of the size heuristic, which could explain the increase in the use of the size heuristic. Nevertheless, the descriptions of the posters by most participants accurately conveyed the key message on the poster and therefore the posters were sufficiently clear for most participants. Furthermore, the use of the activity heuristic was found to have a negative impact on device energy literacy, suggesting that the use of this heuristic may be maladaptive in terms of the estimations of the energy use of household appliances.

Unlike device energy literacy, activity energy literacy did not significantly change after the intervention, and therefore the fourth hypothesis of this study was not supported. This means that the information on the validity of the heuristics, which seems to account for the changed device energy literacy, was not applied to the activity energy literacy task by the participants. Similarly, this suggests that the increased understanding of device energy literacy did not translate into a better understanding of the relative impact of household energy saving behaviours. It remains unclear why the activity energy literacy was not improved after the intervention. Heuristics may not be employed for activity energy literacy tasks and therefore information on these heuristics may not have aided this type of energy literacy.

Alternatively, different types of energy judgement heuristics may be employed to estimate the energy use of activities instead of devices. Perhaps this task is more challenging in nature as it requires the participant to take into account several factors affecting the financial savings of the activities (how much a device is used, the price of electricity etc.). The device rank-order task, on the other hand, may be more straightforward as it involves the estimation of the energy use of household devices for the same amount of time. Furthermore, this task does not require participants to provide an exact estimate of energy use, but rather estimate energy use in comparison to other devices, unlike the activity energy literacy task that required an exact estimate of the annual financial savings. The difference in the difficulty of these tasks is evident in the lower Spearman correlations with the correct answers in activity energy literacy (r_{before}=-

.017, r_{after}=-.032) compared to the device energy literacy (r_{before}=.43, r_{after}=.61). Hence, perhaps the activity energy literacy task was too difficult for participants to improve on – a form of floor effect. This is in line with previous research that has found that people misperceive the impact of household energy saving activities (Attari, Dekay, Davidson, Bruine, & Bruin, 2010).

Furthermore, participants tended to engage in more impactful energy saving behaviour after the intervention, although this effect could not be attributed to improved levels of activity energy literacy, contradicting the fifth hypothesis. Perhaps external factors influenced this behaviour unconsciously (e.g. warmer outdoor temperatures allowed for air-drying clothes or reducing the thermostat). Alternatively, it is possible that the first survey prompted participants to engage in energy saving activities more frequently. Indeed, participants were found to report to engage in the energy saving activities significantly more frequently in the second survey ($t(104)=-2.91$, $p<.01$). Therefore, perhaps participants engaged in all behaviour more often (or at least reported to do so) and thereby increased their energy saving impact.

Finally, and particularly noteworthy given the self-reported increase in impactful energy-saving behaviours, the results showed that there were no changes in objective energy consumption after the intervention. There are various possible explanations for this null finding. First of all, no individual energy consumption data was obtained. Although one could argue that aggregating consumption across flats was beneficial as it reduced individual variation and thereby random error, not all residents of the flats had signed up for the study, which means that the changes in energy consumption could not all be attributed to the intervention. That is, it is likely that if only few residents of a flat had signed up for the study, the efforts of the participants to reduce the energy use may have been cancelled out by the lack of energy saving behaviour from non-participants, who were not incentivised to save energy.

Furthermore, the energy consumption of only 26 flats was included for the analysis because participants of the other flats had dropped out or the energy consumption data could not be obtained for participating flats. Small sample sizes result in large variations and therefore, it is difficult to detect differences (Tabachnick & Fidell, 2013). However, comparing the energy consumption before (M=1115.15, SD=575.60) and after ($M=1123.27$, SD=567.12) the intervention, lack of statistical power may not be the most compelling explanation for the null-findings as the difference between the means is extremely small.

Alternatively, then, it may be that the residents did not have enough behavioural control to reduce their energy use. For example, in most of the campus accommodation, lights switched on and off automatically based on occupancy sensors. Furthermore, washing machines and tumble dryers were not located in the students' flats and therefore any differences in the interaction with these devices were not reflected in the energy consumption data of the flats.

Energy use that participants may have had more control over include kitchen appliances such as kettle, hob and oven, as well as personal appliances such as televisions and laptops.

Another possible explanation for the lack of energy conservation may be insufficient motivation of the participants to save energy in their flats. As residents did not pay for their energy consumption separately (these costs were included in their bills), energy conservation did not reduce their current bills. The £150 prize was introduced to simulate energy conservation incentives, but it is likely that participants felt that the odds to win this prize were small as they may not have expected to be able to save more energy than other flats in their housing blocks (many participants voiced these concerns while filling in the surveys on door-knocking occasions). Participants may have also not have found the incentive worth the effort, as they would have to share the prize with fellow participants in their flat. Although the lack of findings may be a result of a combination of the aggregated data, limited amount of data, lack of behaviour control and lack of motivation, it is expected that participants were mainly not motivated enough to make large changes in their behaviour. That is because even the winners of the prize expressed surprise in regards to their win and admitted that they did not put substantial effort into their energy saving behaviour.

8.4.2 Implications and future research

It may be more likely that the increased levels of energy literacy will translate into energy conservation in a population that will financially benefit from the energy conservation because they pay for their energy bills. Therefore, future research could further explore the relationship between energy literacy and energy saving behaviour among householders, as this could be an excellent opportunity to stimulate household conservation.

The findings in this study suggest that individuals may find it more difficult to estimate the energy impact of household activities than the energy consumption of household devices. Because activity energy literacy may be more closely related to energy saving behaviour than device energy literacy, it is important that this type of energy literacy receives more attention in future research. Specifically, future research could explore how activity energy literacy could be improved as this could inform policy that aims to stimulate energy conservation.

This study was not able to test the hypotheses in relation to the individual differences in energy literacy owing to missing data. That is, it remains unclear if people with stronger environmental values have higher levels of energy literacy (especially as a result of the intervention, which would be particularly interesting), and therefore future research could explore this hypothesis. Furthermore, this study could also not confirm that information on both a valid and an invalid heuristic would be more effective to change energy literacy compared to information on a valid heuristic only, which may imply that the latter information may be sufficient to elicit changes in energy literacy. However, no firm conclusions can be drawn in relation to this due to the lack of differences across conditions in the changes in energy literacy, and therefore future research could test the different types of information provision further, by preventing possible cross-contamination across conditions.

For all the concerns raised about methodological issues, the results of this study do demonstrate that device energy literacy is not an unchanging construct, but in fact can be improved fairly easily. Furthermore, this study shows that the use of heuristics can be addressed through information provision on the validity of the heuristics. This has important theoretical implications as this finding further suggests the deliberate use of heuristics as explicit information provision seemed to have changed the use of the heuristics. This finding also has important practical implications as it shows that device energy literacy can be improved through simple information provision techniques addressing the use of the energy judgement heuristics. Moreover, this also demonstrates a great potential for policy makers who aim to stimulate energy conservation among householders as increasing the awareness of energy consumption in the household is likely to contribute to energy saving behaviour.

8.4.3 Conclusion

Taking all these findings together, this study has shown that energy literacy, as defined by the ability to rank-order appliances by consumption, can be enhanced by changing the use of an appropriate energy judgement heuristic. Information on the validity of this heuristic may have been the cause for people to change the use of the heuristics but the results do not give conclusive evidence for this. Furthermore, using more valid energy estimating heuristics and improved device energy literacy did not increase participants' understanding of the impact of energy saving behaviours nor, perhaps above all, did this result in a reduction in actual measured energy consumption.

Chapter 9: General Discussion

This thesis has investigated both the antecedents of energy conservation as well as energy literacy. The last seven chapters have discussed literature and studies that have investigated these factors. The current chapter summarises and synthesises these findings, discusses their theoretical and policy implications, discusses the limitations of the current findings and suggests avenues for future research before drawing this thesis to a conclusion.

9.1 Summary of the findings

This thesis started with a multiplication model of the drivers and knowledge of energy conservation and the chapters that followed have investigated both of these dimensions. The following sections will briefly summarise the findings of each of these chapters, please refer Table 12 for an overview of the conclusions of each chapter.

Table 12: Conclusions from each chapter in this thesis

	Modelling the antecedents of energy behaviour	**Exploring the antecedents of energy literacy**
Background	Chapter 2: *Reviewing Models and Theories on Energy Behaviour* ------------------------------------ The CADM may be the most successful model to predict energy behaviour, but this has not been tested.	Chapter 5: *Reviewing the Literature on Energy Literacy* ------------------------------------ Energy literacy has been conceptualised in various ways, this thesis will focus on device and activity energy literacy.
Exploration	Chapter 3: *Exploring Perceptions of the Antecedents of their Energy Behaviour* ------------------------------------ Participants' perceptions of their energy behaviour matched the CADM well, but also highlight the relevance of values and environmental identity.	Chapter 6: *Exploring heuristics in Energy Judgements using Qualitative Methods* ------------------------------------ Participants were observed to use 28 different heuristics in an energy judgement task, showing that these judgements are more complex than previously thought.
Investigation	Chapter 4: *Modelling energy behaviour: an application of the Comprehensive Action Determination Model* ------------------------------------ The CADM was successfully replicated to energy behaviour. An extended model including values and environmental identity did not improve the model fit.	Chapter 7: *Quantifying the Awareness of Energy Judgement Heuristics* ------------------------------------ This study showed that participants were somewhat aware of most heuristics identified in Chapter 6 and demonstrates the levels of relative awareness of each heuristic.
Application		Chapter 8: *Improving Energy Literacy by Addressing the use of Energy Judgement heuristics* ------------------------------------ Device energy literacy was improved after an intervention that informed participants about the validity of the heat heuristic and this effect was mediated by the increased use of this heuristic.

The literature review in Chapter 2 critically examined models and theories that could be applied to energy behaviour. Although most models tend to focus on normative and intentional processes, the Comprehensive Action Determination Model (CADM) is the first to integrate these processes with habitual and situational factors (Klöckner & Blöbaum, 2010) that are likely to be relevant to energy behaviour. Literature relating each component of this model to energy behaviour was reviewed and although some factors remained understudied, this review generally suggested that the CADM may successfully predict energy behaviour. No study had yet tested the CADM in relation to energy behaviour, leaving a clear gap in the literature.

The application of the model to energy behaviour was first explored in this thesis with qualitative methods. Specifically, participants' perspectives on the antecedents of energy behaviour were investigated using focus group methodology. These perceptions were mapped onto the CADM with a deductive thematic analysis to reveal the correspondence of the CADM's concepts to people's perceptions of the influences on their energy use. The results showed that, as the CADM would predict, participants frequently discussed social norms and perceived a strong influence of external motivators on their energy behaviour. However, the CADM variables that related to mitigation of environmental problems associated with energy consumption were not perceived to be strong motivators for energy behaviour. Furthermore, an inductive thematic analysis also allowed the identification of other factors pertinent to people's energy behaviours that are not included in the CADM. This analysis revealed the importance of value-orientation and environmental identity, which are not included in the CADM. Moreover, this chapter showed that many CADM constructs were cognitively accessible, including energy habits despite their unconscious influences on behaviour.

Next, the application of the CADM, as well as an extended version of the model that included the additional relevant factors as found in the previous study, were tested using quantitative methods. An online study was conducted in which each variable of the CADM and additional variables were measured. Several models were tested using structural equation modelling and the CADM was found to account for 57% of variation in energy use whereas classical models such as the Theory of Behaviour and Norm Activation Model could only account for 32% and 35% of variance in energy behaviour respectively. These results therefore show that energy behaviour is best explained with models that account for the habitual and situational processes such as the CADM. Indeed, this replication of the CADM demonstrates that this model is not only useful in explaining transportation mode choice (Klöckner & Blöbaum, 2010) but can explain other (environmental) behaviours that are of habitual nature and are context dependent. Although the inclusion of the additional variables did not improve the model fit or increase the explained variance in energy behaviour, biospheric values and environmental identity did improve links within the model. However, limitations of structural equation modelling were highlighted and findings in this chapter should be interpreted in light of these limitations.

Whereas the first part of this thesis looked at what factors determine whether people engage in daily energy saving behaviour, the second part of this thesis focused on people's understanding of the energy use in their household, that is, their energy literacy, which was expected to be more predictive of non-routine energy behaviour. In Chapter 5, existing research on energy literacy was categorised into: energy literacy in relation to home heat control, energy use of devices, knowledge about energy saving activities, economic energy literacy and scientific energy literacy, and the respective literature was critically evaluated. The device energy literacy and energy saving activity literacy were proposed to be most closely related to energy saving behaviour, and were therefore examined further in the following studies. The literature showed that energy judgement heuristics influence people's energy literacy. However, a clear gap in the research was identified as only few studies had investigated a limited number of heuristics in relation to energy literacy.

The study reported in Chapter 6 was the first study that explored the use of energy judgement heuristics in this thesis and aimed to provide a comprehensive account of these heuristics. Using a qualitative approach, participants' rank-ordered household appliances in terms of energy consumption in a group setting. Discussions were recorded and thematic analysis resulted in the identification of as much as 28 different heuristics that were used during the task, which were subsequently categorised into 9 themes. This study demonstrated the vast complexity of the decision making processes which is in sharp contrast with previous literature that had only uncovered two types of heuristics. Moreover, participants only recalled the use of half of the heuristics that they were observed to have been used during the task, suggesting their unawareness of the use of the other half of the heuristics.

Therefore, in Chapter 7, participant's awareness of their use of the energy judgement heuristics was further investigated as well as the decision making complexity of these energy judgements. In an online survey, participants rated household appliances on energy consumption and indicated which of the heuristics uncovered in Chapter 6 they had employed during this energy judgement task. The frequency of the selection of each heuristic was to reflect participants' recognition of the use of the heuristics and thereby their awareness of the use of these heuristic in their energy judgement process. Heuristics were categorised into frequency clusters using cluster analysis and results indicated that participants were most aware of the use of the heat and time switched on heuristic, in line with the findings in the study reported in Chapter 6. However, the frequently observed heuristic in the previous study, the category heuristic, was least recognized by the participants, suggesting people's unawareness of the use of this heuristic. These results therefore illustrated how people may be more strongly aware of the use of some energy judgement heuristics and rather unaware of the use of others. Furthermore, participants were found to report to use almost three heuristics per energy judgement, and this number varied widely across participants and appliances, suggesting that this decision making process is fairly complex.

The final study in this thesis tested whether the use of the heuristics could be influenced by providing information on the validity of the heuristics to improve energy literacy and to stimulate energy saving behaviour. Participants were randomly assigned to three conditions; one where they were informed about a valid heuristic (the heat heuristic), another where they were informed about both a valid and an invalid heuristic (the heat and time switched on heuristic) or a control condition where no information was provided. Results showed no effect of condition on energy literacy or energy savings, which may have been due to cross-contamination across conditions. However, collapsing across conditions, participants were found to have improved their device energy literacy after the intervention, and this effect was mediated by the increased use of the heat heuristic. This study therefore shows that the use of heuristics can be influenced, and that this in turn can increase energy literacy. However, this improved energy literacy did not translate in energy saving behaviour, which was likely due to methodological issues.

9.2 Synthesis of the findings and their theoretical implications

A number of links can be drawn across the findings of the chapters that have explored the antecedents of energy conservation. First, although no previous research has tested the application of the CADM to energy saving behaviour, Chapters 2 to 4 suggest that this model can successfully predict energy conservation. That is, most of the CADM factors have been found to predict energy conservation in previous research, as discussed in Chapter 2. Furthermore, participants' perceptions of the antecedents of their energy behaviour could be mapped onto this model in Chapter 3, and when the model was tested for its predictive power, a large proportion of variance in energy behaviour was explained in Chapter 4. Despite the issues with the statistical methods used in this chapter, this thesis provided strong evidence that the CADM is an appropriate model to predict energy behaviour. Similarly, in previous research the model could predict transportation mode choice (Klöckner & Blöbaum, 2010), recycling behaviour (Klöckner & Oppedal, 2011) and the adaptation of new heating systems (Sopha & Klöckner, 2011), and it is likely that the model can also adequately account for the antecedents of other environmental behaviours.

Furthermore, the current body of work also provides an insight into why the model applies to energy behaviour so well. This model distinguishes itself from traditional models that currently dominate the field of environmental psychology (e.g. Theory of Planned Behaviour, Norm Activation Model), which assume that environmental behaviour mainly follows from intentions and normative processes. The CADM is the first to integrate these factors with habitual and situational factors and the findings in this thesis suggest that this is a clear strength of the model. That is, the literature review showed that the link between habits and energy behaviour is well established, although the situational influences on energy behaviour are understudied. Moreover, previous research shows that energy saving intentions have limited predictive power, due to the intention-behaviour gap. Although participants frequently discussed their energy habits and the situational factors that facilitated or prohibited energy saving behaviour in the study reported in Chapter 3, they tended to emphasise the normative processes and intentions as influential factor for their behaviour more frequently. The replication of the model to energy behaviour in Chapter 4 showed that energy habits was the most important predictor for energy use, and both objective and subjective control over energy consumption also significantly predicted energy use, showing how energy behaviour is a product of automatic processes and the environment.

Social factors, such as personal norms, predicted intentions to save energy well in this study. However, intentions did not in turn predict energy saving behaviour which revealed a clear intention-behaviour gap, a phenomenon that has been consistently demonstrated to occur in many other behaviours (Armitage & Conner, 2001; Bamberg, 2002; Rhodes & De Bruijn, 2013; Sheeran & Orbell, 1998). This could suggest that people tend to perceive strong influences of social factors on their behaviour because they influence their intentions, which is consistent with participants discussions in the study reported in Chapter 3, but they might overestimate the extent to which these intentions actually result in behaviour. That is, these intentions may be overridden by habits or situational constraints or facilitators, which may have more unconscious influences on behaviour. This is in line with research that has demonstrated that when habits are strong, intentions have little effect on behaviour (Verplanken & Wood, 2006). As such, energy behaviour seems to be much more dependent on contextual factors such as habits over which people have much less control than their intentions. Moreover, the importance of contextual factors as facilitators of environmental behaviour has also been confirmed for the uptake of cycling (Beenackers et al., 2012) as well as recycling and waste-management (Olander & Thøgerson, 1995).

Interestingly, the distinction in cognitive systems that has been made in dual-processing theories (introduced in Chapter 5 in relation to the use of heuristics) may also apply here. That is, although these theories were designed to explain differences in cognitive processes rather than antecedents of behaviour, the distinction of *system 1* and *system 2* type of processing may also explain why models such as the Theory of Planned Behaviour (TPB) and Norm Activation Model (NAM) were less successful when accounting for energy behaviour than the CADM. That is, system 1 involves unconscious, effortless and automatic types of processing (Kahneman & Frederick, 2001), and the factors that are unique to the CADM and most predictive of energy behaviour in this thesis, habits and contextual factors, are guided by automatic and unconscious cognitive processes (Aarts et al., 1998; Dijksterhuis, Smith, van Baaren, & Wigboldus, 2005). System 2 involves deliberate, controlled and conscious processing (Kahneman & Frederick, 2001), which models such as the TPB and NAM assume determine behaviour as these models rely on people's intentions and reflections on norms to predict behaviour. This thesis suggests that energy behaviour is more strongly influenced by factors that would fit with the system 1 type of processing because habits and contextual factors affect behaviour in an unconscious and automatic way. However, it needs to be acknowledged that this may not be the case for energy behaviours that involve investments in energy efficiency, which may be more dependent on elaborate thought and intentions, and may therefore be more likely to be guided by system 2 type of processing.

Although the CADM was successfully applied to energy behaviour, the work in this thesis has uncovered other factors that are relevant to energy behaviour that are not included in the model. That is, literature on values and environmental identity suggest that these constructs may be highly relevant to energy behaviour (Abrahamse & Steg, 2011; Gatersleben et al., 2012; Gatersleben et al., 2010; van der Werff et al., 2013; Whitmarsh & O'Neill, 2010). Furthermore, the importance of these factors to energy behaviour became apparent in participants discussions of their energy behaviour in Chapter 3. An extended version of the CADM was therefore tested in Chapter 4, but the results demonstrated that the overall fit of the model did not improve with the inclusion of these factors. Despite the fact that values and environmental identity did have strong links with the existing factors in the model (especially with personal norms), they did not directly predict energy behaviour. This suggests that these factors are important in relation to energy conservation, but their influence on this behaviour is mediated by other factors such as personal norms and intention, much like the other normative variables in the CADM. Therefore, these factors could be incorporated into models that aim to predict behaviour from personal norms or intentions such as the NAM, TPB or Value Belief Norm Theory. However, considering the intention-behaviour gap observed in the application of the CADM in Chapter 4, the addition of these factors may not benefit models that predict behaviour that is more dependent on contextual and habitual factors and therefore the relevance of these factors in relation to this type of behaviour may be questionable.

The chapters that have investigated energy literacy and the decision making processes that precede such energy judgements have uncovered a wealth of findings on these processes. The literature review in Chapter 5 showed that energy literacy has been conceptualised in various ways, but this thesis has mainly focused on device energy literacy as it is most likely to be directly related to conservation behaviour. Within the literature on device energy literacy, a size heuristic and usage pattern heuristic had been identified (Baird & Brier, 1981; Chisik, 2011b; Schuitema & Steg, 2005), yet this thesis has demonstrated that many more energy judgement heuristics are employed that are distinct from these two previously identified heuristics. The study reported in Chapter 6 showed that people may use 28 different kinds of heuristics, which clearly exposes the complexity of this energy judgement process. In the study reported in Chapter 7, participants showed some awareness of all these energy judgement heuristics identified in Chapter 6, except for the category heuristic which may therefore be employed without awareness. Moreover, the findings reported in Chapter 7 suggest that people may be most aware of the use of the heat and time switched on heuristic.

The final study, reported in Chapter 8, suggested that the use of the energy judgement heuristics can be influenced by providing people information on their validity. More importantly, by changing the use of the heuristics, energy literacy was found to improve among participants. Not only do these findings further confirm the influence that these heuristics have on energy judgements, but they also demonstrate that the use of these heuristics can be changed, and are therefore not fixed. This further suggests that people have control over the use of these heuristics and may therefore be using these heuristics deliberately.

Considering the relevance of the CADM and energy literacy for energy conservation, an integration of these two concepts, as proposed in the multiplication model of energy literacy and energy saving drivers in Chapter 1, is essential to adequately account for the antecedents of the different types of energy saving practices. Such an integrative model is likely to provide a comprehensive account of both the antecedents of routine energy curtailment behaviours as well as the antecedents of non-routine energy efficiency behaviours. Moreover, energy behaviour models tend to predict self-reported frequencies of energy behaviour, which do not take into account the impact of the behaviour on energy savings despite the clear relevance of this. That is, without taking the impact of the energy behaviour into account, the validity of these models to predict energy savings is questionable, to say the least. By incorporating individual differences in energy literacy and the use of energy judgement heuristics into a model such as the CADM, it is likely that this model will results in more accurate predictions. Energy literacy may be closely related to objective and subjective behavioural control as the understanding of the energy consumption in one's household allows the householder to identify optimal energy saving behaviours, and thereby control the impact of their energy conservation.

Therefore, the energy literacy component may best be incorporated as a preceding factor of these measures of control in such a model, although it is likely to have a direct effect on energy behaviour as well. Perhaps the inclusion of the energy literacy component may even help to bridge the intention-behaviour gap as knowledge about energy saving may benefit the translation of energy saving intentions to energy saving behaviour. Furthermore, the use of energy judgement heuristics may be included to predict energy literacy. Such a model would need to predict true energy consumption, as energy literacy is unlikely to affect self-report measures that reflect the frequency of (unweighted) energy saving behaviours.

The findings of this thesis suggest that in the context of energy conservation, people do not tend to think and act rationally, as they have limited control of their behaviour and tend to employ a range of heuristics in energy judgements. This is in sharp contrast with economic models of behaviours such as Rational Choice Theory (Archer et al., 1987; Coleman & Fararo, 1992; Feldman, 1987). Indeed, these rational-economic models may not adequately predict environmental behaviour because people do not necessarily think and act in rational and economic ways (Kurz, 2002). Instead, the findings of this study are in line with the concept of bounded rationality in which behaviour is not just a result of a rational thought process, in which all the relevant factors are weighted, but instead, people engage in a process of *satisficing* choices (a combination of satisfying and sufficing) in complex situations (Gigerenzer & Goldstein, 1996; Gigerenzer & Selten, 2002; Simon, 1955, 1982). This concept may explain why social norms and intentions had little influence on energy behaviour in this thesis, as people do not rationally consider all the consequences of their behaviour but rather opt for behaviour that is satisfactory to reach immediate goals i.e. habits (Verplanken & Aarts, 1999). Moreover, this concept has been linked to the use of heuristics because bounded rationality implies that people make decisions based on limited information and do not scrutinise all alternative options because they have a limited capacity to process all the information (Gigerenzer & Selten, 2002).

9.3 Policy implications

This thesis has demonstrated that energy conservation behaviour is mainly dependent on habits and contextual factors and that people's understanding of the energy use in their homes is a result of various energy judgement heuristics. Considering the importance of domestic energy conservation in relation to climate change and fuel poverty (see Chapter 1), and people's willingness to accept many energy-saving policy measures (Gatersleben, 2001), the implications of the findings of this thesis for policy makers and NGO's will be discussed.

First, this thesis has demonstrated that energy behaviour is more dependent on habits and the context in which the behaviour is performed, compared to normative processes and intentions. This suggests that the focus of energy conservation policy should shift from motivating householder to save energy to facilitating this behaviour and the adoption of energy saving habits. For a large part, energy conservation policy consists of soft policy measures, which aim to elicit behaviour change by means of information and persuasion. For example, the Behavioural Insight Team (or the 'Nudge Unit'), a key-player in terms of policy advice, employs nudging techniques that consist of positive reinforcement and indirect suggestions to induce behaviour and attitudinal change without direct instructions of legislation (Cabinet Office Behavioural Insights Team, 2011). As such, this organisation has advised the government to incentivise energy conservation and to take advantage of social norms in energy feedback to stimulate efficient energy use among households (Cabinet Office Behavioural Insights Team, 2011). They argue that this will help households to make *'better choices for themselves'*.

However, financial motivators for energy behaviour are only successful if people make rational choices and behaviour follows from intentions whereas this thesis has demonstrated that daily energy behaviour is unlikely to be a result of these processes. Indeed, the introduction of incentives does not always result in significant reductions of domestic energy use (Asensio & Delmas, 2015) especially when the required effort outbalances the financial incentive (Dogan, Bolderdijk, & Steg, 2014) or harm one's positive self-concept (Bolderdijk, Lehman, & Geller, 2013). Furthermore, such rational-economic models have been suggested to be unsuccessful in inducing energy conservation because it neglects psychological aspects of energy consumption such as perceptions of price and costs (Kurz, 2002). Thus, a rational-choice approach may not be successful in inducing energy conservation because people do not have much control over their day-to-day energy behaviour to make these decisions.

Furthermore, research shows that incorporating social norms in energy feedback only results in marginal energy savings (e.g. 6% for household that consumed above average in Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007). The limited effects of social norms on energy behaviour found in the literature are in line with the findings in this thesis. That is, habits and contextual factors were found to be more predictive of energy behaviour, and these factors should therefore be the focus of policy that aims to induce everyday domestic energy conservation. Addressing the factors that have the strongest influence on energy behaviour is likely to result in a more effective energy conservation policy because habits and contextual factors may over-ride any influences of social norms or intentions.

As such, the findings of this thesis perhaps imply that there is no role for psychology in stimulating domestic energy conservation, and that instead energy conservation policy should be purely based on engineering solutions. That is, this thesis has demonstrated that situational factors have an important influence on energy behaviour which suggests that a psychological approach alone may not always be the optimal approach for energy conservation interventions. Therefore, policy makers may be advised to change the situational factors of the context in which the energy behaviour takes place. In order words, policy makers can endeavour to create environments that facilitate efficient energy behaviour. Homes can be designed or innovated to stimulate energy efficiency that does not depend on householders' behaviour. For example, this can be done through home automation, which involves a control system that automates the use of lights, heating, ventilation, air-conditioning, appliances and security. Such measures do not rely on people's motivations to save energy and thereby overcome the reliance on these factors that were found to have an indirect influence on daily energy use at most. However, research has demonstrated that automation can undermine environmental actions and may impair perceived responsibility to take action (Murtagh, Gatersleben, Cowen, & Uzzell, 2015). Moreover, the absence of environmental behaviour and perceived responsibility is likely to prevent positive spill-over effects into other environmental behaviour (Thøgersen & Ölander, 2003).

Therefore, a better approach for energy conservation policy might be to take the habitual aspects of energy behaviour into consideration in the design of interventions (Kurz, Gardner, Verplanken, & Abraham, 2015). Specifically, interventions aimed to induce energy conservation may be more effective when taking the habit discontinuity hypothesis into account. This hypothesis assumes that behaviour change interventions are more likely to be successful when they coincide with life course changes as this provides a window of opportunity to change habits (Bamberg, 2006; Verplanken, Walker, Davis, & Jurasek, 2008; Verplanken & Wood, 2006; Walker, Thomas, & Verplanken, 2015). This hypothesis has recently gained strong empirically supported in a study that found that interventions that aimed to stimulate sustainable behaviour (including energy conservation) were most successful among households who had recently moved house (Verplanken & Roy, 2016). Considering that energy habits were found to be the strongest predict of energy behaviour, the findings by Verplanken and Roy suggest an excellent opportunity to improve interventions for energy behaviour and change energy habits.

Moreover, the findings of this thesis on energy literacy can inform policy makers how best to help householders that are motivated to save energy. That is, this thesis showed that people's energy judgement processes may be complex, but can be changed to improve the understanding of household energy consumption. Specifically, the study in Chapter 8 has demonstrated that energy literacy can be improved by informing people about the validity of energy judgement heuristics, and thereby revealed a promising opportunity for policy makers to enhance energy understandings. When people are willing to save energy in their homes, knowing which devices and behaviours are the most energy draining will likely empower them to translate their intentions into effective energy saving behaviour. Improving energy literacy may thereby bridge the intention-behaviour gap that was found in this thesis, as an improvement in energy literacy can enhance householders' perceived efficacy to make a significant change in their household energy use.

This approach may be more effective than the current roll-out of smart meters in the UK to give householders control of their energy use. Energy feedback alone has been found to be marginally effective (Bittle et al., 1979; Brandon & Lewis, 1999; Hutton et al., 1986), if effective at all (Katzev et al., 1981), may take time to influence behaviour (Murtagh et al., 2013) and its effect on energy conservation likely depends on householders engagement and enthusiasm for the monitors (Murtagh et al., 2014). The energy feedback provided through smart-meters may be too complex and is not disaggregated (i.e. not appliance specific), which may leave householders unsure which behaviours to change. Information about good ways to estimate the energy use in their household may be easier for people to understand and these energy judgement heuristics can be applied to most aspects of the energy use in their household. For example, the heat heuristic has been found to not only result in more accurate energy estimations, but its use was also increased through information provision in the study reported in Chapter 8. This finding provides an excellent opportunity for policy makers to simply stimulate the use of the heat heuristic among householders to increase energy literacy and thereby empower households to save energy. Considering the strong influence of habits and the opportunity that relocation provides to change these habits, this information may benefit householders most if provided when households relocate. Such an intervention would be congruent with the findings in this thesis as it would address the most important factors influencing energy behaviours and energy literacy.

9.4 Limitations

Although this thesis provided a wealth of insights into the predictors of energy conservation behaviours and people's understanding of their energy use, these findings do need to be interpreted in light of their limitations. First, participants in the studies in this thesis mainly included students and other young people who may not pay for their energy consumption bills. A lack of financial incentives may influence motivations to save energy as well as levels of energy literacy and therefore it is possible that different findings would have been obtained if the studies in this thesis solely included participants who paid for their energy bills. Indeed, participants in the study in Chapter 3 emphasised that they were not currently motivated to save energy due to a lack of financial incentives but predicted that their energy conservation would significantly improve when they would move into private housing accommodation in the following academic year. However, as discussed above, financial incentives do not always result in energy saving behaviour, and the influence of this external motivator may be overestimated by participants. Nevertheless, more research is needed to confirm if the findings in this thesis are relevant for a population that includes a wider ages range and that is responsible for their energy bills.

This thesis has investigated energy saving behaviour, which is the reduction of energy use, with various measures. The CADM was applied to predict energy saving behaviour, however, energy behaviour was measured by self-reported behaviour to replicate the study which first introduced the model (Klöckner & Blöbaum, 2010). Self-reported energy behaviour may be limited in terms of validity (Gatersleben, Steg, & Vlek, 2002), and may therefore not adequately reflect true energy consumption. Hence, it is likely that the variables in the model predict perceived energy consumption, or maybe even levels of energy consumption a person aspires to, as these measures may be subject to social desirability (Abrahamse, Steg, Vlek, & Rothengatter, 2005). However, it is not uncommon for models to be applied to self-reported measures of behaviour, and this type of measure was necessary to adequately compare the application of the model with previous tests of the model. Moreover, considering that people may be unaware of the strong influences of habits and situational factors on their energy behaviour (Maréchal, 2010), the findings of this study can probably not be attributed to the self-report measure in this thesis. In fact, the influences of habits and situational factors may prove even stronger when the model predicts true energy consumption.

Unlike the study reported in Chapter 4, energy saving behaviour in the study reported in Chapter 8 was measured by assessing the change in energy use. These measures may have reflected energy saving behaviour differently in that the self-report of specific energy saving behaviours may be more likely to reflect habitual energy use while a change in energy use reflects the actual change in energy consumption, and thereby the energy conservation. Any small changes in energy behaviour (increase or decrease in energy use) may not have been captured in this measure of energy conservation, especially as they may be counterbalanced with other factors that affect energy use (e.g. change in weather). Therefore, although the energy use measure employed in the study reported in Chapter 8 is more likely to reflect the changes in energy use more accurately, the self-reported measure on energy saving behaviours may be more sensitive to intentional or habitual changes in energy behaviour.

Moreover, the energy behaviours addressed in the studies reported in Chapters 3 and 4 only included better management and curtailment of comfort behaviours, meaning that no efficiency investment behaviour, such as home insulation, was addressed. This means that the findings in these studies are likely to only be relevant to these type of energy behaviours. Indeed, it is unlikely that efficiency investments are as strongly influenced by habits as the other types of energy conservation because they are less likely to occur frequently and may involve more elaborate thought processes when large financial or behavioural investments are required. Although energy behaviours such as better management and curtailment of comfort are more likely to represent daily energy behaviours and therefore occur more frequently, it is also important to investigate the antecedents of efficiency investments because these investments can have a large impact on energy conservation, and therefore energy literacy was investigated in the second part of this thesis. Nevertheless, the antecedents of efficiency investment behaviours could be further explored in future research as the research in this thesis has not been able to demonstrate the influence of energy literacy on energy behaviour and other factors may influence this behaviours as well.

The use of heuristics was investigated in tasks that involved relatively slow energy judgements and in which participants had the opportunity to engage in elaborate decision making processes. This implies that the use of these heuristics may be limited to situations where people consciously try to assess the energy use in their household, and people may not tend to use these in their daily interactions with household appliances, although this should be investigated further. It is therefore possible that the energy judgement heuristics may not be frequently employed, but are mainly used when households are confronted with their energy consumption. These opportunities may occur when householders receive their energy bills or observe their energy use through energy monitors. Therefore, even if these heuristics are not frequently used in people's daily lives, they are most likely to be used when they are most influential: when householders consciously decide to take control of their energy consumption, for example by investing in new appliances or changing the interaction with appliances. This further supports the suggestions above that information on energy judgement heuristics may best be provided to households that are experiencing transitions, as these transitions may facilitate the opportunity for householders to reflect on their energy consumption and invest in the efficiency of their new home.

9.5 Future research avenues

The important implications of this research and the limitations discussed in the previous sections highlight the need for more research on the antecedents of energy use and energy literacy.

First, the generalisability of the findings of this thesis to other populations could be tested in future research. That is, the application of the CADM and the use of energy judgement heuristics could be tested among a sample that pays for their bills and is more demographically representative of the UK population. Moreover, the samples of most of the studies reported in this thesis comprised of students at the University of Bath, who are likely to significantly differ from the general population in terms of age, income and education. Indeed, energy consumption has been found to be strongly affected by such socio-demographic variables (Abrahamse & Steg, 2009), and therefore more research is needed to determine the generalisability of the findings of this thesis.

As discussed above, the CADM should be tested for actual energy consumption to see if it's predictive power holds up for measures of energy use that do not rely on self-report. Moreover, the findings of thesis show that the CADM was successful in predicting energy use, and that this could mainly be attributed to the habitual and situational processes that are incorporated in the model. It is therefore likely that this model may also account for a large proportions of variance in other (environmental) behaviours that are also strongly context dependent or habitual. Indeed, as discussed above, the model has been successfully applied to habitual environmental behaviours such as recycling and transport mode choice (Klöckner & Blöbaum, 2010; Klöckner & Oppedal, 2011), whereas the application was less successful for behaviours that are not habitual such as the adoption of new heating systems (Sopha, Klöckner, & Hertwich, 2011). It is therefore recommended that the model is tested for other environmental behaviours such as environmental consumer behaviour which is also likely to be strongly influenced by habits and is context dependent.

This thesis also showed that incorporating values and environmental identity into the CADM did not improve the overall fit of the model, although these factors did have strong links with personal norms. Specifically, the fit of the model did not improve as personal norms did not have a strong influence on energy behaviour. However, if the model is to be applied to behaviours that are dependent on personal norms, the inclusion of values and environmental identity may improve the predictive power of the model. Moreover, as discussed above, other models that predict behaviour from personal norms and intentions may also benefit from the inclusion of values and environmental identity.

The review of the literature on energy literacy showed that insufficient research has investigated device and activity energy literacy as well as the use of energy judgement heuristics. This thesis has greatly contributed to the existing knowledge on the antecedents of energy literacy, however many aspects of energy literacy remain to be explored. First, the individual differences that can account for levels of energy literacy deserves more research attention as methodological issues prevented the investigation of this link in this thesis. It is important that these individual differences are identified because this will facilitate the development of effective interventions to improve energy literacy. Therefore, future research could further test if individual differences (for example in values, personal norms and environmental identity) can predict levels of energy literacy.

Moreover, the findings of this thesis suggest that energy judgement heuristics are used in slow, elaborate energy judgements. Future research would benefit from investigating if these energy judgement heuristics are also used in quick, automatic energy judgements. Such research could directly compare the use of the energy judgement heuristics in slow and fast energy judgement tasks to provide a rigorous test of the use of the heuristics in different contexts. Furthermore, future research could further explore the awareness of the energy judgement heuristics, as the studies in Chapter 6 and 7 suggested that people are more aware of the use of some energy judgement heuristics than the use of others.

One of the most important findings in this thesis is that device energy literacy can be improved by information provision on energy judgement heuristics. However, this improved energy literacy did not translate into significant household energy saving behaviour. It is likely that energy conservation was not observed due to the sample and other methodological limitations, and therefore future research could further investigate the link between energy literacy and energy conservation. Such research would be extremely valuable as it would highlight the importance of energy literacy in relation to (different types of) energy consumption.

Furthermore, this thesis also suggests that activity energy literacy could not be improved by addressing the use of energy judgement heuristics. Because activity energy literacy may be more closely related to energy saving behaviour than device energy literacy, it is important that this type of energy literacy receives more research attention. Therefore, future research could explore how activity energy literacy could be improved.

Finally, in section 9.2, a model was proposed that incorporates the use of energy judgement heuristics into the CADM to adequately account for various types of energy saving practices. Future research could test this model to predict true energy consumption instead of self-reported energy consumption to reflect the impact of the behaviour. Such a model is most promising and is likely to account for even more variance in energy behaviour than found in Chapter 4. Few models have been applied to measures of actual energy consumption even though such findings are important as they would help the understanding of the predictors of true energy use.

9.6 Conclusions

In closing, this thesis has enhanced the understanding of the factors that influence energy behaviour and the cognitive processes that feed into people's understanding of the energy use in their household. The CADM was found to be successful in predicting energy behaviour due to its inclusion of habitual and contextual factors. Furthermore, this thesis has extended previous research on energy judgement heuristics by identifying and further investigating the use and awareness of more energy judgement heuristics. These findings have important implications for the theory on energy behaviour, as well as for policy makers who aim to stimulate energy conservation in society.

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Appendices

List of Appendices

Appendix A

Definition of CAMD variables and additional concepts used in the thematic analyses in Chapter 3

Table 13: Definition of CADM variables and additional variables

Factors	Definition	Reference
Attitudes	A summary evaluation of an object of thought	Bohner & Wänke, 2002
Awareness of consequences	The extent to which individuals believe their own energy behaviour has negative environmental consequences	Abrahamse & Steg, 2011
Awareness of need	The level of awareness of the adverse consequences of not acting pro-environmentally.	Steg, van den Berg, & de Groot, 2012
Biospheric values	A concern for the quality of nature and the environment for its own sake.	Steg, van den Berg, & de Groot, 2012
Descriptive norms	What most others do (behaviour of parents/peers)	Cialdini, Kallgren, & Reno, 1991
Egoistic values	Concern for the self: People who strongly endorse egoistic values will especially consider costs and benefits for them personally: when the perceived benefits exceed the perceived costs they will behave in a pro-environmental way and vice versa.	Steg, van den Berg, & de Groot, 2012
Environmental behaviour	behaviour that has a positive or negative effect on the environment	Steg, van den Berg, & de Groot, 2012
Environmental identity	the extent to which people indicate that environmentalism is a central part of who they are	Steg, van den Berg, & de Groot, 2012
Habits	Learned sequences of acts that have become automatic responses to specific cues and are functional in obtaining certain goals or end states	Verplanken & Aarts, 1999
Injunctive norms	What most others approve or disapprove (e.g. interventions/advertising/instructions from parents)	Cialdini et al., 1991
Intentions	Assumed to capture the motivational factors that influence a behaviour	Ajzen, 1991
Objective constraints	Objective conditions that limits a person’s freedom to engage in a particular behaviour	

Personal norms	An individual's belief concerning their moral obligations to engage in particular pro-environmental actions	Steg, van den Berg, & de Groot, 2012
Social norms	Person's perceived social pressure to act in a certain way	Klöckner & Blöbaum, 2010
Subjective constraints	people's perception of the ease or difficulty of performing the behaviour of interest	Ajzen, 1991
Value-orientation:	Are desirable trans-situational goals that vary in importance and serve as guiding principles in the life of a person or other social entities.	Steg, van den Berg, & de Groot, 2012

Appendix B

Questionnaire used for studies reported in Chapter 4 and 7

£100 for your thoughts on...

Please answer all questions, except those which do not apply to you.

On questions with seven-point answer scales, choose the point which best represents where you feel you lie between the two extremes given. Don't be afraid to use the whole scale; the central point means you feel half-way between the two extremes. Don't think too much about your answers but go with your first instinct.

A little about you

What is your age?

What is your gender? ◯ Male ◯ Female

What is your nationality? Please select

Do you pay for your energy bills (electricity and gas)? Please select...

What is your current living situation? Please select...
If you said 'other', please specify

How many people currently live in your household (INCLUDING you)?

What do you think?

Which of these options would save more energy? Please select...

Does the thermostat setting affect the speed with which the room will heat up? (e.g. If I want it to be 20 degrees does it help when I set it on 30 degrees?) Please select...

How much energy do appliances use?

How much energy does a **fridge-freezer** use when it is used for **one minute**?

Very little energy per minute ◯ ◯ ◯ ◯ ◯ ◯ ◯ **A lot of energy per minute**

What kind of things did you consider to determine the energy use of a fridge-freezer?

- ☐ **Task size** (e.g., how complex its task is, how many tasks it does)
- ☐ **Physical features of device** (the type, size, number of parts, energy labels)
- ☐ **Temperature** (device changes temperature of water/air/surface or gets hot when in use)
- ☐ **Time** (speed of device, time switched on, how often the device is used)
- ☐ **Variability** (consider different phases of device e.g. usage phase, heating up phase, sustenance, and settings)
- ☐ **My knowledge** (about the Watts used, what I've heard, about its energy efficiency)
- ☐ **Comparison** (different/similar functions as other listed devices, similar category as other devices)
- ☐ **Energy intensity** (e.g. compare task size to the size of the device, its power or activity level)

How much energy does a **oven** use when it is used for **one minute**?

Very little energy per minute ◯ ◯ ◯ ◯ ◯ ◯ ◯ **A lot of energy per minute**

What kind of things did you consider to determine the energy use of a oven?

- ☐ **Task size** (e.g., how complex its task is, how many tasks it does)
- ☐ **Physical features of device** (the type, size, number of parts, energy labels)
- ☐ **Temperature** (device changes temperature of water/air/surface or gets hot when in use)
- ☐ **Time** (speed of device, time switched on, how often the device is used)
- ☐ **Variability** (consider different phases of device e.g. usage phase, heating up phase, sustenance, and settings)
- ☐ **My knowledge** (about the Watts used, what I've heard, about its energy efficiency)
- ☐ **Comparison** (different/similar functions as other listed devices, similar category as other devices)
- ☐ **Energy intensity** (e.g. compare task size to the size of the device, its power or activity level)

How much energy does a **mobile phone charger** use when it is used for **one minute**?

Very little energy per minute ◯ ◯ ◯ ◯ ◯ ◯ ◯ **A lot of energy per minute**

What kind of things did you consider to determine the energy use of a mobile phone charger?

- ☐ **Task size** (e.g., how complex its task is, how many tasks it does)
- ☐ **Physical features of device** (the type, size, number of parts, energy labels)
- ☐ **Temperature** (device changes temperature of water/air/surface or gets hot when in use)
- ☐ **Time** (speed of device, time switched on, how often the device is used)
- ☐ **Variability** (consider different phases of device e.g. usage phase, heating up phase, sustenance, and settings)
- ☐ **My knowledge** (about the Watts used, what I've heard, about its energy efficiency)
- ☐ **Comparison** (different/similar functions as other listed devices, similar category as other devices)
- ☐ **Energy intensity** (e.g. compare task size to the size of the device, its power or activity level)

How much energy does a **microwave oven** use when it is used for **one minute**?

Very little energy per minute ◯ ◯ ◯ ◯ ◯ ◯ ◯ **A lot of energy per minute**

What kind of things did you consider to determine the energy use of a microwave oven?

- ☐ **Task size** (e.g., how complex its task is, how many tasks it does)
- ☐ **Physical features of device** (the type, size, number of parts, energy labels)
- ☐ **Temperature** (device changes temperature of water/air/surface or gets hot when in use)
- ☐ **Time** (speed of device, time switched on, how often the device is used)
- ☐ **Variability** (consider different phases of device e.g. usage phase, heating up phase, sustenance, and settings)
- ☐ **My knowledge** (about the Watts used, what I've heard, about its energy efficiency)
- ☐ **Comparison** (different/similar functions as other listed devices, similar category as other devices)
- ☐ **Energy intensity** (e.g. compare task size to the size of the device, its power or activity level)

How much energy does a **light bulb** use when it is used for **one minute**?

Very little energy per minute ◯ ◯ ◯ ◯ ◯ ◯ ◯ **A lot of energy per minute**

What kind of things did you consider to determine the energy use of a light bulb?

- ☐ **Task size** (e.g., how complex its task is, how many tasks it does)
- ☐ **Physical features of device** (the type, size, number of parts, energy labels)
- ☐ **Temperature** (device changes temperature of water/air/surface or gets hot when in use)
- ☐ **Time** (speed of device, time switched on, how often the device is used)
- ☐ **Variability** (consider different phases of device e.g. usage phase, heating up phase, sustenance, and settings)
- ☐ **My knowledge** (about the Watts used, what I've heard, about its energy efficiency)
- ☐ **Comparison** (different/similar functions as other listed devices, similar category as other devices)
- ☐ **Energy intensity** (e.g. compare task size to the size of the device, its power or activity level)

How much energy does a **hair dryer** use when it is used for **one minute**?

Very little energy per minute ○ ○ ○ ○ ○ ○ ○ **A lot of energy per minute**

What kind of things did you consider to determine the energy use of a hair dryer?

- ☐ **Task size** (e.g., how complex its task is, how many tasks it does)
- ☐ **Physical features of device** (the type, size, number of parts, energy labels)
- ☐ **Temperature** (device changes temperature of water/air/surface or gets hot when in use)
- ☐ **Time** (speed of device, time switched on, how often the device is used)
- ☐ **Variability** (consider different phases of device e.g. usage phase, heating up phase, sustenance, and settings)
- ☐ **My knowledge** (about the Watts used, what I've heard, about its energy efficiency)
- ☐ **Comparison** (different/similar functions as other listed devices, similar category as other devices)
- ☐ **Energy intensity** (e.g. compare task size to the size of the device, its power or activity level)

How much energy does a **kettle** use when it is used for **one minute**?

Very little energy per minute ○ ○ ○ ○ ○ ○ ○ **A lot of energy per minute**

What kind of things did you consider to determine the energy use of a kettle?

- ☐ **Task size** (e.g., how complex its task is, how many tasks it does)
- ☐ **Physical features of device** (the type, size, number of parts, energy labels)
- ☐ **Temperature** (device changes temperature of water/air/surface or gets hot when in use)
- ☐ **Time** (speed of device, time switched on, how often the device is used)
- ☐ **Variability** (consider different phases of device e.g. usage phase, heating up phase, sustenance, and settings)
- ☐ **My knowledge** (about the Watts used, what I've heard, about its energy efficiency)
- ☐ **Comparison** (different/similar functions as other listed devices, similar category as other devices)
- ☐ **Energy intensity** (e.g. compare task size to the size of the device, its power or activity level)

How much energy does a **tumble dryer** use when it is used for **one minute**?

Very little energy per minute ○ ○ ○ ○ ○ ○ ○ **A lot of energy per minute**

What kind of things did you consider to determine the energy use of a tumble dryer?

- ☐ **Task size** (e.g., how complex its task is, how many tasks it does)
- ☐ **Physical features of device** (the type, size, number of parts, energy labels)
- ☐ **Temperature** (device changes temperature of water/air/surface or gets hot when in use)
- ☐ **Time** (speed of device, time switched on, how often the device is used)
- ☐ **Variability** (consider different phases of device e.g. usage phase, heating up phase, sustenance, and settings)
- ☐ **My knowledge** (about the Watts used, what I've heard, about its energy efficiency)
- ☐ **Comparison** (different/similar functions as other listed devices, similar category as other devices)
- ☐ **Energy intensity** (e.g. compare task size to the size of the device, its power or activity level)

How much energy does a **laptop computer** use when it is used for **one minute**?

Very little energy per minute ○ ○ ○ ○ ○ ○ ○ **A lot of energy per minute**

What kind of things did you consider to determine the energy use of a laptop computer?

- ☐ **Task size** (e.g., how complex its task is, how many tasks it does)
- ☐ **Physical features of device** (the type, size, number of parts, energy labels)
- ☐ **Temperature** (device changes temperature of water/air/surface or gets hot when in use)
- ☐ **Time** (speed of device, time switched on, how often the device is used)
- ☐ **Variability** (consider different phases of device e.g. usage phase, heating up phase, sustenance, and settings)
- ☐ **My knowledge** (about the Watts used, what I've heard, about its energy efficiency)
- ☐ **Comparison** (different/similar functions as other listed devices, similar category as other devices)
- ☐ **Energy intensity** (e.g. compare task size to the size of the device, its power or activity level)

How much energy does a **washing machine** use when it is used for **one minute**?

Very little energy per minute ○ ○ ○ ○ ○ ○ ○ **A lot of energy per minute**

What kind of things did you consider to determine the energy use of a washing machine?

- ☐ **Task size** (e.g., how complex its task is, how many tasks it does)
- ☐ **Physical features of device** (the type, size, number of parts, energy labels)
- ☐ **Temperature** (device changes temperature of water/air/surface or gets hot when in use)
- ☐ **Time** (speed of device, time switched on, how often the device is used)
- ☐ **Variability** (consider different phases of device e.g. usage phase, heating up phase, sustenance, and settings)
- ☐ **My knowledge** (about the Watts used, what I've heard, about its energy efficiency)
- ☐ **Comparison** (different/similar functions as other listed devices, similar category as other devices)
- ☐ **Energy intensity** (e.g. compare task size to the size of the device, its power or activity level)

What is important to you?

Please rate the following items:

I know ways to save energy (even if I may not do it).	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
When I save energy, the fact that this reduces my impact on climate change is a nice by-product.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
If I reduce my personal energy use, I contribute to climate protection.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
Energy use contributes to climate change.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
I try to save energy for the environment, and if this saves me money as well that's a happy accident	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
My intention to use less energy in the next seven days compared to the last seven days for my daily activities (showering, controlling the radiator, doing the laundry etc.) is strong.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
I think of myself as an environmentally-friendly consumer.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
People in my country make an effort to save energy	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
The aspect of environmental protection in my energy use is solidly anchored in my value system.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
I would be embarrassed to be seen as having an environmentally friendly lifestyle.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
My personal energy use affects the quality of life for future generations.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
I would not want my family or friends to think of me as someone who is concerned about environmental issues.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
My friends consider their energy use in their daily activities.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
People who are important to me insinuate that I should consider environmental protection when I consider my energy use.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
I think of myself as someone who is very concerned with environmental issues.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
People who are important to me expect that I will use energy in an environmentally friendly way.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**

My personal decision to use energy has consequences for global ecological damage.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
Due to values important to me, I feel obliged to use as little energy as possible.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
Energy use is an urgent problem for environmental protection.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
Due to my values/principles, I feel personally obliged to use environmentally friendly means of energy such as a renewable energy.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
I think my family embers try to limit their energy use	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
People who are important to me support me when I curtail my energy use.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
It would be difficult to manage my energy use in an environmentally friendly way.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
I intend to use less for my daily activities (showering, controlling the radiator, doing the laundry, etc.) in the next seven days compared to last week.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
I believe that using energy causes many environmental problems.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
Circumstances force me to use a lot of energy	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
How much do each of these guide your life:			
Protecting the environment	**I aspire to the opposite of this**	○ ○ ○ ○ ○ ○ ○	**I aspire to this**
Having social power	**I aspire to the opposite of this**	○ ○ ○ ○ ○ ○ ○	**I aspire to this**
Unity with nature/feeling connected with nature	**I aspire to the opposite of this**	○ ○ ○ ○ ○ ○ ○	**I aspire to this**
Obtaining wealth	**I aspire to the opposite of this**	○ ○ ○ ○ ○ ○ ○	**I aspire to this**
Being able to influence other people	**I aspire to the opposite of this**	○ ○ ○ ○ ○ ○ ○	**I aspire to this**
Respecting the earth	**I aspire to the opposite of this**	○ ○ ○ ○ ○ ○ ○	**I aspire to this**
Having authority over other people	**I aspire to the opposite of this**	○ ○ ○ ○ ○ ○ ○	**I aspire to this**
Preventing pollution	**I aspire to the opposite of this**	○ ○ ○ ○ ○ ○ ○	**I aspire to this**
Please indicate how often you engaged in the following behaviours over the past week			
Air-dry clothes instead of using a tumble dryer	**Never**	○ ○ ○ ○ ○ ○ ○	**Every time**
Switching the T.V. off instead of leaving it on stand-by	**Never**	○ ○ ○ ○ ○ ○ ○	**Every time**
Putting a lid on a saucepan when boiling water	**Never**	○ ○ ○ ○ ○ ○ ○	**Every time**
Unplugging my phone charger when it is done charging	**Never**	○ ○ ○ ○ ○ ○ ○	**Every time**
Switching off the radiator instead of opening the window when the room is hot	**Never**	○ ○ ○ ○ ○ ○ ○	**Every time**
Only boiling the amount of water I need in the kettle	**Never**	○ ○ ○ ○ ○ ○ ○	**Every time**
Switching off the light when I leave the room	**Never**	○ ○ ○ ○ ○ ○ ○	**Every time**
Wearing a jumper instead of turning up the radiator when I'm cold	**Never**	○ ○ ○ ○ ○ ○ ○	**Every time**
Switching the computer off/putting it in sleep mode when I leave the house	**Never**	○ ○ ○ ○ ○ ○ ○	**Every time**
Wash on 30 degrees	**Never**	○ ○ ○ ○ ○ ○ ○	**Every time**
Please tell us about your reasons for your behaviour:			
When you take action to save energy, what is the reason for this?	**Only to save money**	○ ○ ○ ○ ○ ○ ○	**Only for the environment**
Please answer the following questions:			
Can you control the thermostat in your accommodation?	Please select...		
Can you control your radiator in your accommodation?	Please select...		
Can you control the lights in your accommodation?	Please select...		
Can you control the settings on the washing machine?	Please select...		
Thinking about my energy consumption in my daily activities is something that...			
...is part of my routine.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
...does not require any active thought.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
...I do totally automatically.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
...gives me a strange feeling when I don't do it	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
...is typical for me.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
...I do without thinking about it.	**Strongly disagree**	○ ○ ○ ○ ○ ○ ○	**Strongly agree**
That's the end! If you would like to have a chance of winning the £100 voucher then please enter your email address here. **This will be stored separately to all your answers above**			

Submit your answers

Appendix C

Supplementary material on the method of SEM used in Chapter 4

SEM answers the question ‘could this model have led to the data I have?’ as opposed to traditional statistics in which a model is applied to the data. That is, SEM assesses whether the model produces an estimated population covariance matrix that is consistent with the sample covariance matrix (Ullman, 2013). When the covariance matrices are not significantly different, the model is said to fit the data adequately (Ullman, 2013). SEM assumes that the residuals are not correlated with each other or with other variables in the model (Ullman, 2013). For more details and an algebraic example of this method, the highly useful work by Ullman (2013) can be consulted.

As the method is a development of such correlational techniques as multiple regression modelling, causal relations can only be inferred from SEM when the design of the study meets the relevant conditions such as time precedence and robust relationships when other variables are present or absent (Lei & Wu, 2007; Ullman, 2013). SEM consists of a measurement model and a structural model, the next few sessions will provide more details on these models.

Measurement model

Because the latent constructs included in the model cannot be measured directly, these are estimated through a number of observable variables (Lei & Wu, 2007). The Measurement model in Figure 31 shows the relationship between the latent variables variable (in this example X) and the observed variables (here X1, X2 and X3). These observed variables (also called measured variables, indicators or manifest variables) are depicted in the model with squares or rectangles and latent variables (or constructs/unobserved variables) are represented by ovals. If multiple parameters are loading onto a latent variable, one parameter needs to be constrained to serve as a reference point for the other parameters (Ullman, 2013). The measurement error of each observable variable is accounted for by including them into the model (e1, e2 and e3 in Figure 31) (Lei & Wu, 2007). SEM uses confirmatory factor analysis to estimate the loadings of the observed variables on the latent variables. CFA uses structures that are hypothesised a priori as opposed to exploratory factor analysis that bases the structures on the data itself (Lei & Wu, 2007). With CFA, indicators can load on multiple factors and therefore residuals are allowed to correlate (Lei & Wu, 2007).

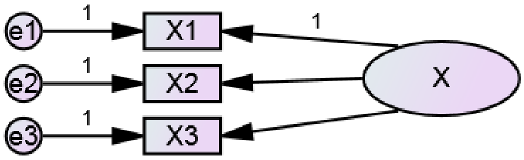

Figure 31: Example of a measurement model

Structural model

The structural model reflects the hypothesised relations between latent variables only (Ullman, 2013). SEM allows for the modelling of mediation in that variables can serve as both exogenous (which is equivalent to an independent variable) variables as well as endogenous (which is equivalent to a dependent variable) variables (Lei & Wu, 2007). An example of this can be seen in Figure 32 in which variable A and B are exogenous variables predicting endogenous variable X and Y. However, variable X is also an exogenous variable predicting endogenous variable Y. For the measurement model, structural equations are modelled that are hypothetical causal relations among observed variables (Lei & Wu, 2007). The lines between the variables represent the relationships between the variables, whereas the absence of a line suggests that there is no direct relationship hypothesised. A line with one arrow implies that a direct relationship is hypothesised, with the variable that the arrow points at being the dependent variable. A line with an arrow on both sides suggests a relationship that has not been analysed but covariance between the two variables is implied without any direction of the effect. The error of the dependent variables is called disturbance and is included in the model for each endogenous variable, reflecting variation in indicator variable scores that are not accounted for by the latent variable (Kline, 2005) (D1 and D2 in Figure 32).

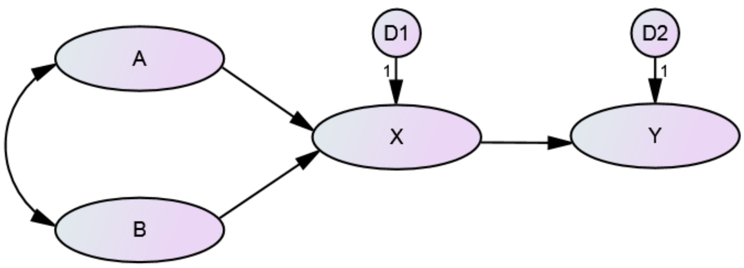

Figure 32: Example of a structural measurement model

Appendix D

Selection of Model fit indices in Chapter 4

When evaluating the model fit, the null hypothesis that is to be tested is that the data fits the specified model (Lei & Wu, 2007). The discrepancy between the observed covariance matrix and the covariance matrix as proposed by the specified model is tested and reflected in a model fit index statistic. Although the chi-square statistic is the most popular to be reported with SEM as it is the only model fit index with a significance test (Kline, 2005), type 1 errors are likely when the sample size is small (n <500) and the model complex, meaning that the models are rejected unnecessarily (Bearden, Sharma, & Teel, 1981). However the likelihood of type 2 errors (meaning that the model is accepted when it should be refused) are substantial even when samples are large (Fornell & Larcker, 1981). To overcome this problem, many alternative fit indices have been developed with researchers free to choose which model indices they report. Many authors recommend using a combination of indices as some indices may be more reliable under certain conditions than others (Lei & Wu, 2007).

Different types of model fit indices have been developed: absolute fit measures that judged the fit of the model without reference to other models (Blunch, 2013); the relative fit measures that compare the model fit to the fit of a baseline model (Kaplan, 2009), parsimony adjusted measures correct for a good fit that is due to the inclusion of a large number of parameters thereby taking into account the complexity of the model (Blunch, 2013) and fit measures based on the non-central chi-square distribution assume that models can only be approximately correct (Blunch, 2013). As the indices within these categories tend to measure the same aspect of the model, one model fit index per category will be reported as recommended in the SEM literature (e.g. Blunch, 2013).

The absolute fit measure that is often recommended to be included is the Standardised Root Mean square Residual (SRMR) (Hu & Bentler, 1999; Kline, 2005) that allows for differences in measurement scales (Ullman, 2013). This measure is based on the covariance residuals which is the difference between the observed and predicted covariances and therefore small values indicate a good model fit (a cut-off value of <.10 has been recommended) (Kline, 2005).

The relative fit measure that is consistently recommended in the SEM literature is the Comparative Fit Index (CFI) (Byrne, 2010; Hu & Bentler, 1999; Ullman, 2013). This fit index is based on the goodness of fit index and the norm fit index that have been adjusted by taking the degrees of freedom of the model into account because these indices tended to underestimation the fit for small sample size (Blunch, 2013). The CFI compares the researcher's model to a null model that assumes no covariance among observed variables (Kline, 2005). CFI values above .90 are considered to reflect a good model fit (Kline, 2005).

The Akaike information criterion (AIC) has been found to be the best performing model parsimony indicator available (Williamsa & Holahan, 1994). This index is used to compare across proposed models that may differ in the numbers of latent variables (Schumacker & Lomax, 2010). An AIC value needs to be compared to the AIC values across different models to compare parsimony (Norman & Streiner, 2003). Unlike the other model fit indices it is not scaled from 0 to 1 and AIC values closer to 0 indicate a better model fit and thus a more parsimonious model (Schumacker & Lomax, 2010). Therefore, the model with the lowest AIC index has the most parsimonious fit (Norman & Streiner, 2003).

The Root Mean Square Error of Approximation (RMSEA) is a fit measures based on the non-central chi-square distribution and also takes the complexity of the model into account (Kline, 2005). It has often been recommended to assess model fit with this index as it is sensitive to model misspecification and tends to yield appropriate conclusions on model fit (Byrne, 2010; Hu & Bentler, 1999; Maccallum, Browne, & Sugawara, 1996; Ullman, 2013). Values <.06 have been suggested to indicate a good fit (Hu & Bentler, 1999) and value >.10 reflect a poor fit (Maccallum et al., 1996).

In sum, the model fit indices that will be reported to evaluate the model fit of the models to be tested are the SRMR, CFI, AIC and RMSEA. As Klöckner and Blöbaum (2010) also reported the RMSEA, SRMR and CFI the choice of these indices will allow for direct comparisons of model fit.

Appendix E

Pre and post-transformation scores for indicator variables in Chapter 4

Table 14: Skew of the observed variables before and after transformation

Variable	Original Skew	Skew Post-Transform	Transformation used
AC1	-.57	.51	Reversed Ln(x)
AC2	-1.11	.23	Reversed Ln(x)
AC3	-1.00	.17	Reversed Ln(x)
AN1	-1.29	-.15	Reversed Ln(x)
AN2	-.61	.50	Reversed Ln(x)
AN3	-.88	.14	Reversed Ln(x)
BIO1	-.74	.51	Reversed Ln(x)
BIO2	-.41	.33	Reversed Ln(x)
BIO3	-.53	.50	Reversed Ln(x)
BIO4	-.52	.56	Reversed Ln(x)
DN1	-.06	-	
DN2	-.22	-	
DN3	-.40	-	
EnvID1	-2.09	-1.27	Reversed Ln(x)
EnvID2	-1.72	-.95	Reversed Ln(x)
EnvID3	-.33	.73	Reversed Ln(x)
EnvID4	-.35	.80	Reversed Ln(x)
H1	-.42	.51	Reversed Ln(x)
H2	-.05	.89	Reversed Ln(x)
H3	-.70	.35	Reversed Ln(x)
H4	-.70	.30	Reversed Ln(x)
H5	-.70	.27	Reversed Ln(x)
H6	-.55	.41	Reversed Ln(x)
Int1	.15	-	
Int2	.15	-	
IN1	.18	-	
IN2	-.31	-	
IN3	-.20	-	
PBC1	-1.0	.63	Reversed Ln(x)
PBC2	-1.47	-.24	Reversed Ln(x)
PBC3	-.430	.28	Reversed Ln(x)
PN1	-.19	-	
PN2	-.32	-	
PN3	-.19	-	

OC1	-4.22	-	
OC2	-.84	-	
OC3	-3.20	-	
OC4	-3.20	-	
Beh1	-2.33	-1.07	Reversed Ln(x)
Beh2	-1.54	-.85	Reversed Ln(x)
Beh3	-1.00	-.52	Reversed Ln(x)
Beh4	-2.00	-1.28	Reversed Ln(x)
Beh5	-.75	.01	Reversed Ln(x)
Beh6	-1.01	-.49	Reversed Ln(x)
Beh7	-1.36	-.30	Reversed Ln(x)
Beh8	-.72	-.14	Reversed Ln(x)
Beh9	-.82	-.06	Reversed Ln(x)
Beh10	-.48	.02	Reversed Ln(x)
Squared total skew prior to transformation			**76.74**
Squared total skew post-transformation			**51.02**

BIO= Biospheric values, AN= Awareness of Need, AC= Awareness of Consequences, IN= Injunctive Norms, DN= Descriptive norms, EI= Environmental Identity, PBC= Perceived Behavioural Control, PN= Personal Norms, OC= Objective Control, H= Habits, INT= Intention, BEH= Behaviour

Appendix F

Appliances in order of amount of energy consumption in Chapter 6

Table 15: List of appliances in order of energy consumption as presented to participants in the study reported in Chapter 6

Rank	Appliance	Wattage per hour	Wattage per minute
1.	Tumble dryer	3150w	52.5 w
2.	Oven	2400w	40 w
3.	Kettle	2300w	38.33 w
4.	Electric hob	2000w	33.33 w
5.	Heater (portable)	1280w	21.33 w
6.	Microwave	1195w	19.92 w
7.	Hair dryer	1184w	19.73 w
8.	Toaster	1150w	19.17 w
9.	Clothes Iron	1100w	18.33 w
10.	Coffee machine	950w	15.83 w
11.	Hoover	940w	16.67 w
12.	Washing machine	700w	11.67 w
13.	Fridge freezer	570w	9.5 w
14.	Desktop computer	235w	3.92 w
15.	Stereo	200w	3.33 w
16.	T.V.	160w	2.67 w
17.	Lights (student room)	150w	2.5 w
18.	Game system	125w	2.08 w
19.	Electric blanket (Single)	90w	1.5 w
20.	Laptop	40w	0.67 w
21.	DVD player	35w	0.58 w
22.	Phone charger	5w	0.08 w
23.	Electric toothbrush	1.5w	0.025 w

Appendix G

First questionnaire used for the study reported in Chapter 8

Informed consent, page 1/6

1. We would like to invite you to participate in this research project. Please read the following information. If you have any questions please don't hesitate to contact us.

Aims of the Research
With this study, we would like to learn about your energy consumption and about your attitudes.

Explanation of Procedures
If you decide to participate in this study, you will be asked to fill out two online questionnaires, one at the beginning of the study, and one at the end. Each questionnaire will take about 5-10 minutes for you to fill in. You will be asked to try to reduce your energy use during this semester. The participants of the hall which saved the most energy by the end of term will jointly win £150.

Confidentiality
All the information which will be collected through this study will remain confidential. Participants' identity will not be revealed to any external parties. All research materials will be kept in a locked office at the University of Bath.

Risks and Discomforts
We do not anticipate that participation in this study will pose physical or psychological risks beyond what you encounter in everyday life. The questions you will be asked will not be personal or involve any sensitive topics. However, you may also terminate the questionnaire at any time, without explanation or penalty although this will mean that you won't be able to win the prize.

Benefits
The results from this study will add to knowledge about energy consumption and could improve interventions designed to curtail households' energy use.

Freedom to Withdraw Participation
Participation in this study is voluntary; you will not be penalized if you decide not to participate. You are free to withdraw consent and end your participation in this project at any time.

Contact for further information:
Karlijn van den Broek
klvdb20@bath.ac.uk
Eastwood buildings 20/21
Claverton Down
Bath
BA2 7AY

If you are happy to participate, please tick the following box:

☐ I have read and understood the information above and I agree to take part in the research.

Demographics, page 2/6

2. What is your age?

3. What is your gender?

- Male
- Female

4. In which building on campus do you live?

- Eastwood
- Norwood House
- Westwood

5. What is your room number on campus? Please Include building, floor and room number where applicable using the following format examples:
Eastwood 86.5 (Eastwood building 86, room 5)
Wolfson L5.16 (Westwood, buidling Wolfson, floor 5, room 16)
Norwood 10.22 (Norwood, floor 10, room 22)

Rating household devices 3/6

With the following questions, it is very important that you do not consult any (online) resources or confer with other people. It's ok if you find these questions difficult, you don't need to get them right.

6. Please rank-order the following 10 household devices in terms of energy consumption, considering their energy use for one minute of continuous use.
Please rank the device that you think uses most energy on the top (as number 1), and the device that uses least energy on the bottom (as number 10).

- [ ] Kettle
- [ ] Hair dryer
- [ ] Oven
- [ ] Mobile phone charger
- [ ] Tumble dryer
- [ ] Laptop
- [ ] Toaster
- [ ] Fridge freezer
- [ ] Microwave
- [ ] Light bulb

7. When you rank-ordered these devices in the last question, to what extent did you considering the following aspects of the device in order to estimate their energy consumption?

	Did not consider this at all	Hardly considered this	Somewhat considered this	Significantly considered this	Strongly considered this
Whether the device increases the temperature of air/surface/water	○	○	○	○	○
The size of the device	○	○	○	○	○
How long the device is generally switched on for	○	○	○	○	○
How fast the device completes its job.	○	○	○	○	○
How active the device is	○	○	○	○	○
How energy intense the device is	○	○	○	○	○

8. Please indicate how often you engage in the following activities:

	never	rarely	sometimes	frequently	every/all the time
Setting your washing machine to 30 degrees	○	○	○	○	○
Using a bowl rather than a running tap when washing up	○	○	○	○	○
Only boiling the water that you need	○	○	○	○	○
Switching the lights off when you leave the room	○	○	○	○	○
Air-dry your laundry instead of using a tumble dryer	○	○	○	○	○
Turn off appliances that are left on standby and are not in use	○	○	○	○	○
Turning the thermostat down by 1 degree Celsius	○	○	○	○	○
Using an energy saving light bulbs instead of an old light bulbs	○	○	○	○	○

9. Please estimate how much money a typical household can save by performing the following energy saving activities per year.

	Less than £10 per year	£10-£20 per year	£20-30 per year	£30-40 per year	£40-50 per year	£50-60 per year	More than £60 per year
Setting your washing machine to 30 degrees	○	○	○	○	○	○	○
Using a bowl rather than a running tap when washing up	○	○	○	○	○	○	○
Only boiling the water that you need	○	○	○	○	○	○	○
Switching the lights off when you leave the room	○	○	○	○	○	○	○
Air-dry your laundry instead of using a tumble dryer	○	○	○	○	○	○	○
Turn off appliances that are left on standby and are not in use	○	○	○	○	○	○	○
Turning the thermostat down by 1 degree Celsius	○	○	○	○	○	○	○
Using an energy saving light bulbs instead of an old light bulbs	○	○	○	○	○	○	○

What do you think? Page 4/6

10. Please rate how much you agree with the following statements:

	Strongly disagree	Disagree	Somewhat disagree	Undecided	Somewhat agree	Agree	Strongly Agree
Due to values important to me, I feel obliged to use as little energy as possible	○	○	○	○	○	○	○
Due to my personal values, I feel personally obliged to use environmentally friendly means of energy such as a renewable energy	○	○	○	○	○	○	○
Protecting the environment through my energy use fits my personal values	○	○	○	○	○	○	○
People who are important to me expect that I will use energy in an environmentally friendly way	○	○	○	○	○	○	○
People who are important to me would say that I should consider environmental protection when I consider my energy use	○	○	○	○	○	○	○
People who are important to me would support me to curtail my energy use	○	○	○	○	○	○	○
People in the UK make an effort to save energy.	○	○	○	○	○	○	○
Other residents on campus try to conserve energy.	○	○	○	○	○	○	○
My friends consider their energy use in their daily activities	○	○	○	○	○	○	○
My family members try to limit their energy use	○	○	○	○	○	○	○
Saving energy is an important part of who I am	○	○	○	○	○	○	○
I am the type of person who saves energy	○	○	○	○	○	○	○
I see myself as a person who saves energy	○	○	○	○	○	○	○

11. Considering my energy use in my daily activities is something that...

	Strongly disagree	Disagree	Somewhat disagree	Undecided	Somewhat agree	Agree	Strongly Agree
…gives me a strange feeling when I don't do it.	○	○	○	○	○	○	○
…I do totally automatically.	○	○	○	○	○	○	○
…I do without thinking about it.	○	○	○	○	○	○	○
…is part of my routine.	○	○	○	○	○	○	○
…is typical for me.	○	○	○	○	○	○	○
…does not require any active thought.	○	○	○	○	○	○	○

What is important to you? 5/6

12. We each have deep-seated values that guide the choices we make in our lives. Please rate the importance of these 16 values as guiding principles in your life.
Please vary your response, and only rate a few values as extremely important.

	-1 opposed to my principles	0 not important at all	1	2	3	4	5	6	7 extremely important
INFLUENTIAL: having an impact on people and events	○	○	○	○	○	○	○	○	○
RESPECTING THE EARTH: harmony with other species	○	○	○	○	○	○	○	○	○
HELPFUL: working for the welfare of others	○	○	○	○	○	○	○	○	○
WEALTH: material possessions, money	○	○	○	○	○	○	○	○	○
PREVENTING POLLUTION: protecting natural resources	○	○	○	○	○	○	○	○	○
SELF-INDULGENT: doing pleasant things	○	○	○	○	○	○	○	○	○
AMBITIOUS: hard-working, aspiring	○	○	○	○	○	○	○	○	○
SOCIAL POWER: control over others, dominance	○	○	○	○	○	○	○	○	○
EQUALITY: equal opportunity for all	○	○	○	○	○	○	○	○	○
PLEASURE: joy, gratification of desires	○	○	○	○	○	○	○	○	○
UNITY WITH NATURE: fitting into nature	○	○	○	○	○	○	○	○	○
A WORLD AT PEACE: free of war and conflict	○	○	○	○	○	○	○	○	○
AUTHORITY: the right to lead or command	○	○	○	○	○	○	○	○	○
SOCIAL JUSTICE: correcting injustice, care for the weak	○	○	○	○	○	○	○	○	○
ENJOYING LIFE: enjoying food, sex, leisure, etc.	○	○	○	○	○	○	○	○	○

	-1 opposed to my principles	0 not important at all	1	2	3	4	5	6	7 extremely important
PROTECTING THE ENVIRONMENT: preserving nature	○	○	○	○	○	○	○	○	○

Thank you for your participation! 6/6

Thank you for completing this questionnaire!

Now you can start saving energy in your flat to have a chance to win £150 if your flat saves the most energy!

You will receive another email in 2 months time in which you will be asked to complete an even shorter questionnaire. After this questionnaire we will announce who is the winner of the £150!

Meanwhile, if you have any questions, feel free to email Karlijn van den Broek at klvdb20@bath.ac.uk.

Appendix H

Second questionnaire used for the study reported in Chapter 8

Demographics, page 1/3

Hi!

Thank you for filling out the last few questions for this challenge! By filling in these few questions you are making sure that you don't miss out on the opportunity to win £150 if your flat has saved the most energy in the last few weeks! You are also helping to understand how we can motivate residents to reduce their energy use, plus you are helping me finishing my PhD! A big thank you to you!

Filling in these questions shouldn't take you much longer than 2-3 minutes.

Thanks!

* 1. What is your age?

* 2. What is your gender?

- Male
- Female

* 3. In which building on campus do you live?

- Eastwood
- Norwood House
- Westwood

* 4. Please fill in this question exactly as you did before.

What is your room number on campus? Please Include building, floor and room number where applicable using the following format examples:
Eastwood 86.5 (Eastwood building 86, room 5)
Wolfson L5.16 (Westwood, buidling Wolfson, floor 5, room 16)
Norwood 10.22 (Norwood, floor 10, room 22)

Rating household devices 2/3

With the following questions, it is very important that you do not consult any (online) resources or confer with other people. It's ok if you find these questions difficult, you don't need to get them right.

* 5. Please rank-order the following 10 household devices in terms of energy consumption, considering their energy use for one minute of continuous use.
Please rank the device that you think uses most energy on the top (as number 1), and the device that uses least energy on the bottom (as number 10).

- [ ] Kettle
- [ ] Hair dryer
- [ ] Oven
- [ ] Mobile phone charger
- [ ] Tumble dryer
- [ ] Laptop
- [ ] Toaster
- [ ] Fridge freezer
- [ ] Microwave
- [ ] Light bulb

* 6. When you rank-ordered these devices in the last question, to what extent did you considering the following aspects of the device in order to estimate their energy consumption?

	Did not consider this at all	Hardly considered this	Somewhat considered this	Significantly considered this	Strongly considered this
Whether the device increases the temperature of air/surface/water	◯	◯	◯	◯	◯
The size of the device	◯	◯	◯	◯	◯
How long the device is generally switched on for	◯	◯	◯	◯	◯
How fast the device completes its job.	◯	◯	◯	◯	◯
How active the device is	◯	◯	◯	◯	◯
How energy intense the device is	◯	◯	◯	◯	◯

* 7. Please indicate how often you engage in the following activities in the past week:

	never	rarely	sometimes	frequently	every time/all the time
Setting your washing machine to 30 degrees	◯	◯	◯	◯	◯
Using a bowl rather than a running tap when washing up	◯	◯	◯	◯	◯
Only boiling the water that you need	◯	◯	◯	◯	◯
Switching the lights off when you leave the room	◯	◯	◯	◯	◯
Air-dry your laundry instead of using a tumble dryer	◯	◯	◯	◯	◯
Turn off appliances that are left on standby and are not in use	◯	◯	◯	◯	◯
Turning the thermostat down by 1 degree Celsius	◯	◯	◯	◯	◯
Using an energy saving light bulbs instead of an old light bulbs	◯	◯	◯	◯	◯

* 8. Please estimate how much money a typical household can save by performing the following energy saving activities per year.

	Less than £10 per year	£10-£20 per year	£20-30 per year	£30-40 per year	£40-50 per year	£50-60 per year	More than £60 per year
Setting your washing machine to 30 degrees	○	○	○	○	○	○	○
Using a bowl rather than a running tap when washing up	○	○	○	○	○	○	○
Only boiling the water that you need	○	○	○	○	○	○	○
Switching the lights off when you leave the room	○	○	○	○	○	○	○
Air-dry your laundry instead of using a tumble dryer	○	○	○	○	○	○	○
Turn off appliances that are left on standby and are not in use	○	○	○	○	○	○	○
Turning the thermostat down by 1 degree Celsius	○	○	○	○	○	○	○
Using an energy saving light bulbs instead of an old light bulbs	○	○	○	○	○	○	○

2/3 last few questions!

9. Did you notice a new poster about energy consumption in your kitchen in the last few weeks?

○ Yes

○ No

○ Not sure

10. If so, can you describe the main message of the poster?

Thank you for completing this questionnaire!

The winning flat of the energy saving challenge will be announced over the next 2 weeks. All the participating residents of the winning flat will receive an email.

If you have any questions, feel free to email Karlijn van den Broek at klvdb20@bath.ac.uk.

Appendix I

Results of mediation analyses on activities energy literacy from Chapter 8

The effect of study phase on activity energy literacy was not found to be significant (c=-0.02, $\chi^2(1)=0.24$, p=.63) meaning that activity energy literacy was unchanged after the intervention. However, because a significant total effect is not a requirement for mediation to occur (MacKinnon, Krull, & Lockwood, 2000), mediation analyses was performed to assess if any changes in the use of energy estimating heuristics mediated the relation between study phase and activity energy literacy.

Mediation model for the size-heuristic

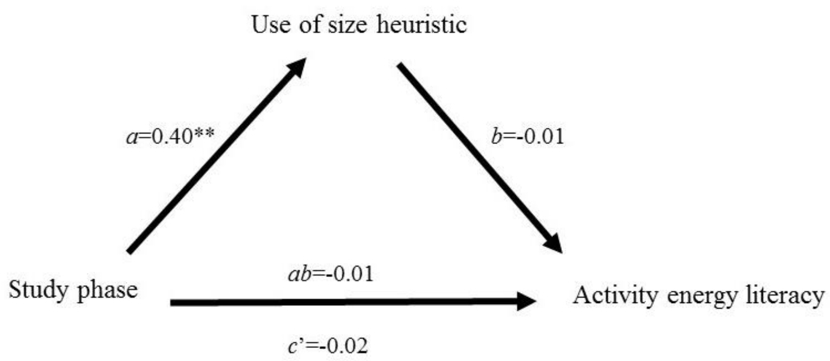

Figure 33: Diagram of the mediating effect of the size heuristic. The diagram displays regression coefficients of the direct effect of study phase on activity energy literacy and the indirect effects through the use of the size heuristic
*Note:**<.01*

The residual plot confirmed homoscedasticity and the absence of outliers for this mediation analysis. The results of the mediation analysis for the use of the size heuristic (see Figure 33) showed a non-significant mediation effect on activity literacy (ab=-0.01, 95% CI [-0.03, 0.02]. The direct effect of study phase on activity energy literacy remained insignificant as would be expected with an insignificant indirect effect (c'= -0.02, 95% CI [-0.12, 0.10]). As was found in the mediation analysis in section 8.3.1.1, participants indicated to use the size heuristic more often after the intervention (a=0.40, $\chi^2(1)=8.48$, p<.01), yet using this heuristic did not have an effect on the accuracy of the financial estimations of household energy saving activities (b=-0.01, $\chi^2(1)=0.078$, p=.78).

Mediation model for the intensity heuristic

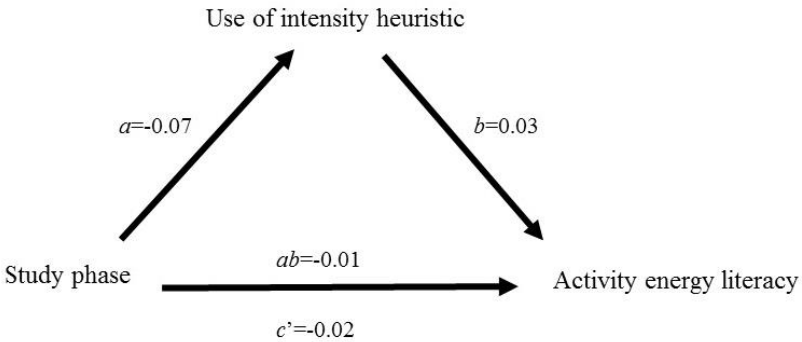

Figure 34: Diagram of the mediating effect of the intensity heuristic. The diagram displays regression coefficients of the direct effect of study phase on activity energy literacy and the indirect effects through the use of the intensity heuristic

Homoscedasticity assumptions and the absence of outliers was confirmed by the residual plot for this mediation analysis. No significant mediation effect was found for the intensity heuristic (see Figure 33), meaning the use of the intensity heuristic did not account for any changes in the activity energy literacy (*ab*=-0.01 95% CI [-0.02, 0.01]). Again, the direct effect of study phase on activity energy literacy was not found to be significant (*c*'=-0.02, 95% CI [-0.12, 0.09]). Furthermore, the use of this heuristic was not found to differ across study phases (*a*=-0.07, $\chi^2(1)=0.62$, *p*=.43) nor did the use of this heuristic have an effect on how well participants could estimate the energy use of the appliances (*b*=0.03, $\chi^2(1)=0.52$, *p*=.47).

Mediation model for the activity heuristic

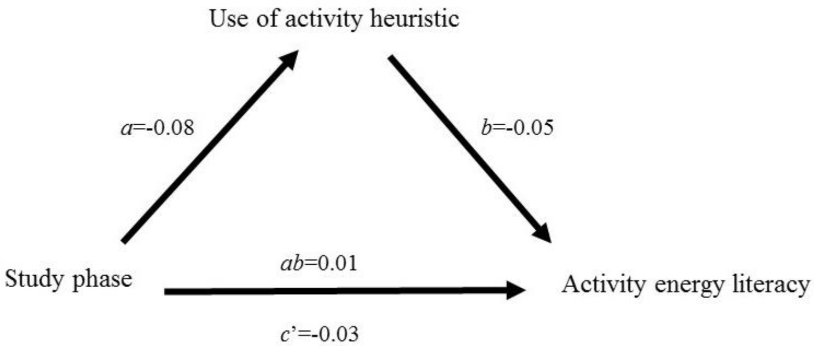

Figure 35: Diagram of the mediating effect of the activity heuristic. The diagram displays regression coefficients of the direct effect of study phase on activity energy literacy and the indirect effects through the use of the activity heuristic

The residual plot confirmed assumptions of homoscedasticity and the absence of outliers for this mediation analysis. The use of the activity heuristic was not found to significantly mediate the effect of study phase on activity energy literacy (*ab*=0.01, 95% CI [-0.01, 0.02], see Figure 35. The direct effect of study phase on activity energy literacy was still not significant as would be expected with an insignificant indirect effect (*c*'=-0.03, 95% CI [-0.12, 0.08]). The use of this heuristic was unchanged across study phases (*a*=-0.08, $\chi^2(1)= 0.52$, *p*=.47). However, the more participants reported to use this heuristic, the lower their activity energy literacy scores tended to be although this effect was bordering on significance (*b*= -0.05, $\chi^2(1)=3.75$, *p*=.05), suggesting that the use of this heuristic negatively impacts the accuracy of the financial saving estimations of energy saving behaviour.

Mediation model for the heat heuristic

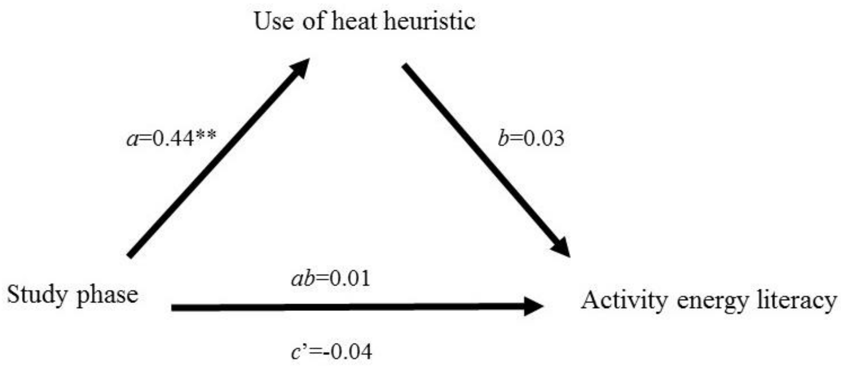

Figure 36: Diagram of the mediating effect of the heat heuristic. The diagram displays regression coefficients of the direct effect of study phase on activity energy literacy and the indirect effects through the use of the heat heuristic
*Note:**<.01*

Again, homoscedasticity assumptions were met and no outliers were present for this mediation analysis. No significant mediation effect was found for the heat-heuristic (see Figure 36) (*ab*=0.01, 95% CI [-0.01, 0.04]). Furthermore, the direct effect of study phase on activity energy literacy was still not significant (*c*'=-0.04, 95% CI [-0.15, 0.08]). Study phase had a positive effect on the use of the heat heuristic, meaning that participants used this heuristic more after the intervention (*a*=0.44, $\chi^2(1)= 8.14$, *p*<.001), as reported in section 8.3.1.4. However, the use of this heuristic had no impact on the accuracy of the financial estimates (*b*= 0.03, $\chi^2(1)=1.63$, *p*=.20).

Mediation model for the speed heuristic

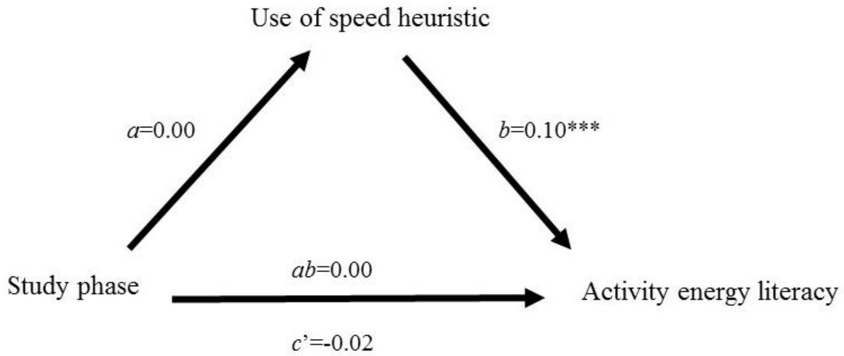

Figure 37: Diagram of the mediating effect of the speed heuristic. The diagram displays regression coefficients of the direct effect of study phase on activity energy literacy and the indirect effects through the use of the speed heuristic
*Note: ***<.001*

The residual plot revealed homoscedasticity and no outliers meaning that assumptions for this mediation analysis seemed to hold. As expected, no mediation effect was found for the speed heuristic (*ab*=0.00 95% CI [-0.03, 0.03], see Figure 37). Because the mediation effect was practically 0, *c'* equalled *c* which was a significant direct effect of study phase on activity energy literacy (*c*'=-0.02, 95% CI [-0.01, 0.08]). Furthermore, the frequency with which participants reported to use this heuristic remained the same after the intervention (*a*=0.00, $\chi^2(1)= 0.00$, $p=1$). Interestingly, the more participants reported to use the speed heuristic, the better their estimations of the financial impact of energy saving activities were (*b*= 0.10, $\chi^2(1)=16.14$, $p<.001$).

Mediation model for the time switched on heuristic

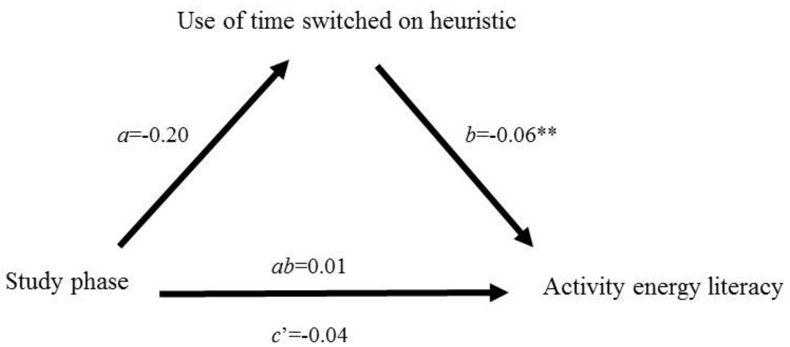

Figure 38: Diagram of the mediating effect of the time switched on heuristic. The diagram displays regression coefficients of the direct effect of study phase on activity energy literacy and the indirect effects through the use of the time switched on heuristic
*Note:**<.01*

Assumptions of homoscedasticity were met and no outliers were present as shown by the residual plot. The use of the time switched on heuristic could not be proven to mediate the relation between study phase and activity energy literacy (*ab*=0.01, 95% CI [-0.01, 0.04]. Furthermore, the direct effect of study phase on the performance on the ranking task was not found to be significant (*c*'=-0.04, 95% CI [-0.13, 0.06]). As reported in section 8.3.1.6, this heuristic was not significantly used less in the rank-order task after the intervention, although the coefficient did suggest a declining tendency to use this heuristic (a= -0.20, $\chi^2(1)$= 1.97, p=.16). The negative impact of the use of this heuristic on the accuracy of the energy estimations was confirmed (b= -0.06, $\chi^2(1)$=7.38, p<.01).